International Journal of Environmental Science and Development, Vol.2, No.1, February 2011
ISSN: 2010-0264

Study on Anaerobic Treatment of Synthetic Milk Wastewater under Variable Experimental Conditions

Abdulsalam Tawfeeq Dawood, Arinjay Kumar, S. S. Sambi

***Abstract*—This paper is concerned with the investigation of various phases of the anaerobic treatment of synthetic milk wastewater under variable experimental conditions. The dairy industry wastewaters contain high concentrations of organic matter and therefore requires proper treatment prior to discharge. There is, however, lack of experimental data available for the various important temperature ranges (psychophillic, mesophilic, thermophilic) and other parameters like organic loading rate and retention time. The investigation has been made to comprehend the degree of wastewater stabilization in terms of COD at variable temperature, organic loads and retention times, with and without providing additional seeds for the treatment in the batch reactor. The study is focused on finding out the *optimal parameters* for efficient biodegradation of organics in the milk wastewaters. These experiments have been performed in a baffled anaerobic batch reactor. Experimental results show that the percentage COD reduction increases with time for all the considered cases. The organic loading affects the COD reduction significantly. The percentage COD reduction at 35^{0}C without additional seeds, has been observed at the lower organic loading 1g/l and retention time of 72 h to be 50.00%. Whereas the COD reduction is 83.33% with seeds, under same conditions. As organic loading increases, the percentage COD reduction decreases; a phenomenon that has been observed in all the temperature ranges. The three different peaks of percentage COD reduction have been found out at the above mentioned temperature ranges for both with and without seeds cases.**

***Index Terms*—Dairy Wastewater, Anaerobic Treatment, COD Reduction, Variable Organic Loading.**

Manuscript received November 12, 2010. This work was supported in part by the University School of Chemical Technology, Guru Gobind Singh Indraprastha University, Delhi, India, the Indian Council for Cultural Relations (ICCR), as well as the Ministry of Higher Education and Scientific Research, Baghdad, Iraq.

Abdulsalam Tawfeeq Dawood (corresponding author) is an ICCR PhD Research Scholar with the Guru Gobind Singh Indraprastha University, Kashmere Gate, Delhi 110403, India, and also with the Ministry of Higher Education and Scientific Research, Baghdad, Iraq (Mobile 0091-9899835818; e-mail: abdulsalamtawfiq@yahoo.com).

Arinjay Kumar is an Associate Professor with the University School of Chemical Technology, Guru Gobind Singh Indraprastha University, Kashmere Gate, Delhi 110403, India. (Mobile 0091-9868613719; e-mail: arinjay10766@rediffmail.com).

S. S. Sambi is a Professor with the School of Chemical Technology, Guru Gobind Singh Indhraprastha University, Kashmere Gate, Delhi 110403, India. (Mobile 0091-9312065265; Phone 0091-11-23900241, Fax: 0091-11-23900240, e-mail: sambi1950@yahoo.co.in).

I. Introduction

India is a large producer of milk and dairy products in the world with annual milk production crossing 85 million tones in the year 2002, and growing at the rate of 2.8% per annum [1]. The dairy industry wastewaters are generated primarily from the cleaning and washing operations in the milk processing plants and are estimated to be 2.5 times the volume of the milk processed. Thus, some 200 million tons of wastewaters are generated annually from the Indian dairy industry. Dairy waste effluents consist of carbohydrates, proteins and fats originating from the milk. Moreover, the dairy industry produces different products, such as milk, butter, yoghurt, ice-cream, various types of desserts and cheese, thus, the characteristics of these effluents also vary greatly, depending on the type of system and the methods of operation used [2]. Since, dairy waste streams contain high concentrations of organic matter; these effluents may cause serious problems, in terms of organic load on the local municipal sewage treatment systems. The treatment techniques may include physico-chemical and biological treatment methods. But, the biological processes are generally preferred due to high chemical costs and the poor soluble COD removability in physical–chemical treatment processes. Among the various biological treatment technologies available, anaerobic treatment is generally employed as this treatment can easily handle the varying organic loads and the temperature ranges encountered. The variable COD concentrations, warm and strong dairy effluents are ideal for anaerobic treatment. Furthermore, no requirement for aeration, low amount of excess sludge production and low area demand are additional advantages of anaerobic treatment processes [3] The sequencing batch reactor (SBR) system might be suitable to treat milk industry wastewater because of its ability to reduce nitrogen compounds by nitrification and de-nitrification, but the SBR system still has some disadvantages such as the high excess sludge produced and the high sludge volume index [4]. Biological processes based upon SBR are effective for organic carbon removal in domestic and industrial wastewater. In SBR operation, each reactor in the system has five basic operating modes or periods. The periods are the fill, react, settle, draw and idle [5]. The duration, oxygen concentration and mixing in these periods could be altered according to the needs of the particular treatment plants. In a temperature range between 5 and 20^{0}C, and at hydraulic retention time (HRT) range between 24 and 6 h, soluble organic removal rates ranged between 62 and 90% for COD, and 75 and 90% for BOD_5. In another laboratory-scale work,

two-stage thermophilic ASBR systems provided volatile solids (VS) removal of 26–44%, while mesophilic ASBR systems achieved VS removal between 26 and 50% for dairy wastewater [3]. The modified SBR treatment system was observed able to provide continuous sewage wastewater inflow and retain ease of operation and high treatment efficiencies of the conventional SBR treatment system [6]. The most significant advantage of anaerobic baffled reactor is its ability to separate acidogenesis and methanogenesis longitudinally down the reactor, allowing the different groups of bacteria to develop under most favorable conditions [7]. Three cycles were run under batch operation mode in order to assess the feasibility of a sequential process to efficiently mineralize a real dairy wastewater rich in fat. In each new cycle the maximum cumulative methane production was improved, and the volatile fatty acids (VFA) levels decreased significantly [8]. Therefore, in the present study, an attempt has been made to carry out the experiment in a baffled anaerobic sequencing batch reactor to reduce the time of treatment of dairy wastewater.

II. Literature

The sequencing batch reactor (SBR) has received considerable attention since Irvine and Davis (1971) including the full description of its operation. The SBR system is a modern version of the *fill and draw* system, consisting of one or more tanks, each capable of waste stabilization and solid separation [9]. Veysel Eroglu et al. [10] have also reviewed various aspects of sequencing batch reactors with respect to treatment efficiency and experimental conditions. Anaerobic sequencing batch reactors (ASBR) are generally employed for treating dairy effluents. ASBR provides high treatment efficiencies for dairy effluents. Banik and Dague in another laboratory-scale work [11] reported the laboratory-scale ASBR system to provide soluble COD and BOD_5 removal rates of 62 and 75%, respectively, at an HRT of 6 h, at 5^0C, for a synthetic substrate of non-fat dry milk. In a temperature range between 5 and 20^0C, and at retention time ranged between 24 and 6 h, soluble organic removal rates ranged between 62 and 90% for COD, and 75 and 90% for BOD_5. Dugba and Zhang [12] reported two-stage thermophilic ASBR systems provided volatile solids removal of 26–44%, while mesophilic ASBR systems achieved VS removal between 26 and 50% for dairy wastewater. The systems have been operated for organic loading of 2–4 g VS/l day and at retention time of 3 and 6 days. Ruiz et al. [13] has discussed the purification performance and the basic fundamentals for the design of an ASBR used for treating concentrated dairy wastewater. The maximum loading has been determined to be 6 g COD/l day for stable operation. However, higher loadings have been reported to cause sludge removal problem and also decrease in purification efficiency. Mohan et al. [14] reported the dairy wastewater treatment in a suspended growth sequencing batch reactor at mesophilic temperature 28^0C and observed 64.7% COD removal efficiency.

The literature review shows lacking of experimental investigation in variable temperature ranges (psychophillic, mesophilic and thermophilic) along with other conditions. Therefore, in the present study an attempt has been made to investigate the degree of waste stabilization in terms of COD at variable organic loading, time of treatment and temperatures with and without additional seeds for the treatment in sequencing batch study. The study focuses on to finding out the optimal parameters for efficient biodegradation of organics from milk wastewaters to reduce the time.

III. Materials And Method

A. Experimental Setup

Bench scale anaerobic batch reactor with suspended growth configuration was designed and fabricated in the laboratory using plastic material with a working volume of 1.0 L (gas holding capacity, 0.5 L; liquid volume, 1.0 L) as depicted in Fig. 1. The reactor was fabricated using leak proof sealing along with proper inlet and outlet arrangements. Feed was introduced from top of the reactor, and operated in suspended mode employing magnetic stirrer mechanism for keeping biomass in suspension during operation. The reactor was operated in batch mode with a total retention time period of 72 h with an increment of 24 h. Furthermore, two baffle walls have been provided inside the reactor to making three separate chambers. A more promising solution for stabilising an ABR during the start-up period and shock loading regimes would be to eliminate the harsh conditions in the initial compartments of the reactor and to provide sufficient substrate for the anaerobic bacteria in the final compartments of the reactor [15]. Initially, the effluent has been filled in first chamber and the effluent changes from aerobic to anaerobic mode as well as anaerobic microorganisms acclimatize there.

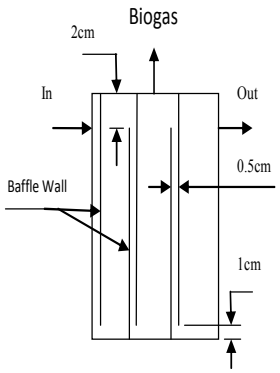

Fig. 1: Schematic of the experimental setup consisting batch reactor

B. Dairy Synthetic Wastewaters

The characteristics and composition of mixed effluent from different processing units of dairy wastewater has been shown in Table I below. The synthetic milk wastewaters equivalent to the above characteristics have been prepared in the laboratory using Nestle EveryDay milk powder. The milk powder has following composition as shown in Table II. Thus, the synthetic milk wastewaters of different organic loading have been prepared using different weight of milk powder. Furthermore, the actual COD values have been verified each time before initiation of experimental work.

C. Preparation of Additional Seeds

The experiments have been planned for reducing the time

period of anaerobic treatment. Therefore, experiments have been performed with and without providing additional seeds. The additional seeds for experimentation have been obtained using pre-prepared culture media from synthetic milk waste and sewage. Table III shows the composition of culture media (nutrients solution) used in the experimentation. 100 ml nutrients solution has been used in 395 ml synthetic milk waste and 5ml of sewage. The mixture has been kept for 3 weeks at 30^0C temperature for growing the anaerobic bacteria. Thereafter, this mixture has been used as additional seeds at the rate of 2ml/l for anaerobic treatment.

D. Experimental Conditions

Temperature variation: As a general rule, the rate of biological activity doubles for every 10 to 15^0C temperature rise within the range of 5 to 35^0C .Above 40^0C mesophilic activity drops off sharply and thermophilic growth starts. Thermophilic bacteria have a range of approximately 45 to 75^0C, with an optimum near 55^0C [16]. Therefore, the experiments have been performed at various temperatures with an increment of 10 to 15^0C, i.e. at 15^0C, 25^0C, 35^0C, 45^0C and 55^0C. These temperature covers all three temperatures ranges i.e., psychrophilic (0 –20^0C), mesophilic (20 – 42^0C) and thermophilic (42 – 75^0C) range [17]. *Organic loading variation:* In dairy effluents, one of the key parameter BOD ranges from 0.8 g/l to 2.5 g/l (0.8 kg/ton to 2.5 kg/ton) [18]. Therefore in present study, the organic loading has been varied from 1 g/l to 3 g/l with an increment of 0.5 g/l in present experimental work. With this organic loading the equivalent COD comes out to be 1250 to 3750 mg/l.

Time variation: The retention time has also been varied from 24 h to 72 h with an increment of 24h.

TABLE I: CHARACTERISTICS AND COMPOSITION OF DAIRY WASTEWATERS SOURCE: [16].

S. No.	Parameters	Typical values, mg/l
1	COD	3290
2	BOD	1400
3	pH	7
4	Suspended Solid	300
5	Nitrogen	50
6	Phosphorus	12

TABLE II: COMPOSITION OF MILK POWDER PER 100 GRAMS AS MENTIONED BY THE MANUFACTURER.

S. No.	Parameters	Typical values, gm
1	protein	20.5
2	carbohydrate	52.7
3	sugar	23
4	fat	19

TABLE: III COMPOSITION OF NUTRIENTS SOLUTION.

Compound	Concentration (g/l)	compound	Concentration (g/l)
NH_4Cl	2.8	$CaCl_2$	0.076
KH_2PO_4	2.0	$NaHCO_3$	4
$MgSO_4.7H_2O$	0.1		

E. Experimental Procedure

The experiments have been performed following above mentioned experimental conditions. The chemical oxygen demand (COD) has been measured for different temperatures (15, 25, 35, 45 and 55^0C), organic loadings (1.0, 1.5, 2.0, 2.5 and 3.0 g/l) and the retention times (24, 48, and 72 h). In fact, anaerobic digestion has a small pH tolerance range of 6.7 to 7.4 with optimum operation at pH 7.0 to 7.1[16]. Therefore, pH, 7.0 has been maintained in present experimental work. Further, other requisite conditions for a particular experiment have been maintained and the COD has been measured at specified time period as per standard method.

IV. RESULTS AND DISCUSSION

The results of percentage COD removal in anaerobic treatment of synthetic milk wastewater at different experimental conditions have been discussed herein. The results of COD removal with and without providing additional seeds along with variable organic loads and time have been thoroughly discussed.

A. COD Removal without Additional Seeds at Variable Organic Loads and Time (without seeding)

Fig. 2 shows the percentage COD reduction in anaerobic treatment of synthetic milk wastewater at 15^0C constant temperature, in a batch operation. The values of COD clearly indicate that maximum percentage removal 33.33% takes place at lower organic loading 1g/l and maximum time 72h. However, a minimum removal of 17.33% has been observed at higher organic loading 3.0g/l and time, 72h. The reason may be more acclimatization period taken by anaerobic bacteria at higher organic loads. Possibly, if we increase the time, the COD reduction will be increased. Furthermore, the percentage COD reduction decreases with increase in organic loadings monotonically for different time.

Fig. 3 illustrates the percentage COD reduction at 25^0C constant temperature, in a batch operation. The values of COD clearly show that maximum percentage removal 25.00% has been obtained at lower organic loading 1g/l and time, 72h. However, a minimum removal of 12.00% has been observed at higher organic loading 3.0g/l and time, 72h. Here also, the reason may be more acclimatization period taken by anaerobic bacteria at higher organic loadings. The percentage COD reduction decreases with increase in organic loadings monotonically for different time.

Fig. 4 illustrates the percentage COD reduction at 35^0C constant temperature, in a batch operation. The values of COD show that maximum percentage removal 50.00% observed at lower organic loading 1g/l and time, 72 h. However, a minimum removal of 25.33% has been observed at higher organic loading 3.0g/l and time, 72h. The reason may be same as previously described. The percentage COD reduction decreases with increase in organic loadings but not monotonically for different time as in previous cases. The COD reduction at 24h and 48h, time follows different pattern than at 72 h time. However, at time 72 h, the trend of COD reduction follows the previous cases.

Fig. 5 depicts the percentage COD reduction at 45^{0}C constant temperature, in a batch operation. The values of COD show that maximum percentage removal 20.83% observed at lower organic loading 1g/l and time, 72 h. However, a minimum removal of 9.33% has been observed at higher organic loading 3.0g/l and time, 72 h. The reason may be same as previously described. The percentage COD reduction decreases with increase in organic loadings monotonically for different time as in previous cases.

Fig. 6 illustrates the percentage COD reduction at 55^{0}C constant temperature, in a batch operation. The values of COD show that maximum percentage removal 41.66% observed at lower organic loading 1g/l and time, 72 h. However, a minimum removal of 26.66% has been observed at higher organic loading 3.0g/l and time, 72 h. The reason may be same as previously described. The percentage COD reduction decreases with increase in organic loading rates monotonically for different time as in previous cases.

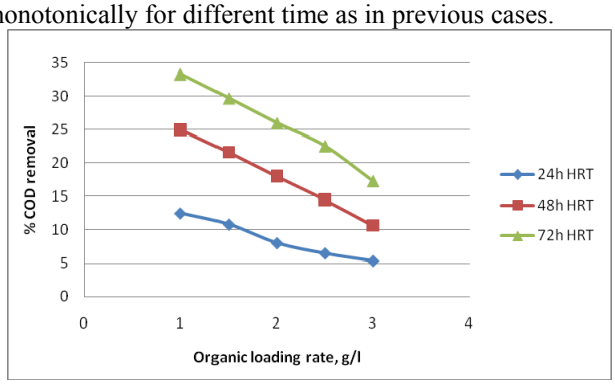

Fig. 2: % COD removal under variable organic loadings and time at 15^{0}C temperature.

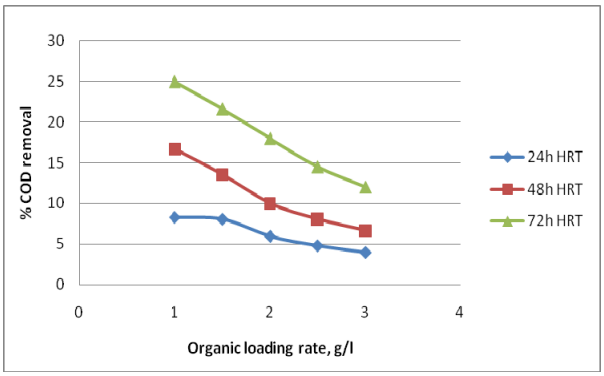

Fig. 3: % COD removal under variable organic loadings and time at 25^{0}C temperature

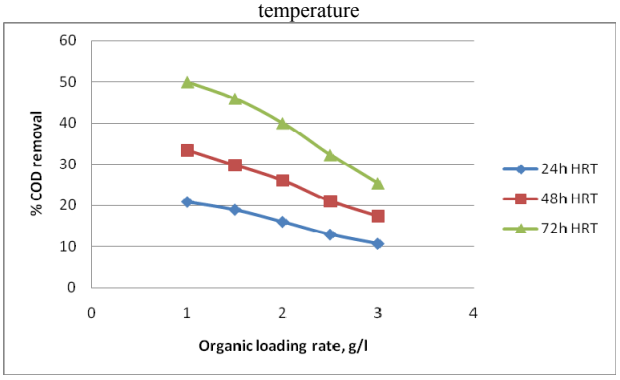

Fig. 4: % COD removal under variable organic loadings and time at 35^{0}C temperature

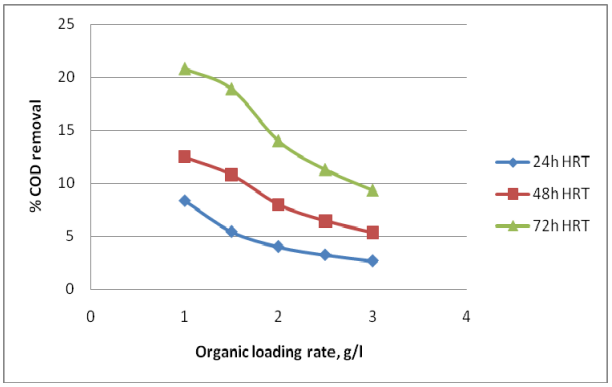

Fig 5: % COD removal under variable organic loadings and time at 45^{0}C temperature

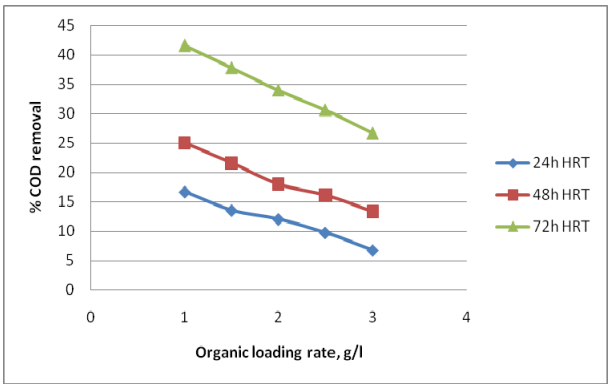

Fig. 6: % COD removal under variable organic loadings and time at 55^{0}C temperature

B. Comparison in COD Removal Efficiency at Variable Temperature, Organic Loading and Time

Fig. 7 illustrates the three different peaks of percentage COD reduction at different temperature ranges i.e., psychrophilic (0–20^{0}C), mesophilic (20 – 42^{0}C) and thermophilic (42 –75^{0}C) range. First peak of COD reduction lies on psychrophilic (0 – 20^{0}C) range, at which maximum COD removal takes place and thereafter, it decreases with increase in temperature. The percentage COD reduction has been observed to be minimum at 25^{0}C because it lies in the initiation of mesophilic (20 – 42^{0}C) zone. The maximum percentage of COD reduction has been found to be at 35^{0}C temperature which is mid of mesophilic (20 – 42^{0}C) zone. The temperature 45^{0}C is close to lower range of thermophilic zone that is why the percentage COD has been observed to be much lesser than that of at 35^{0}C temperature. The percentage COD reduction at 55^{0}C temperature has been found to be much more than that at 45^{0}C temperature. This may be due to efficient working of thermophilic microorganisms at 55^{0}C temperature. These three dimensional mesh view (Fig. 7 Fig. 8 and Fig. 9) clearly demonstrate that temperature and organic loadings have substantial effect on percentage reduction of COD. This is also evident that the wastewater had a mixed culture consisting of a mixed types of micro organisms. This indicates that one has to be very cautious while designing such units as there is a lot of variation in weather conditions in India during a year. They also give the intermediate values of COD reduction at various temperature levels and organic loadings.

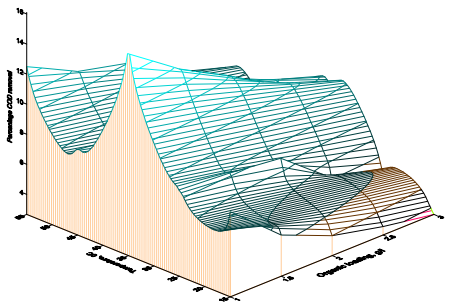

Fig. 7: Percentage COD removal under variable temperature and organic loading for 24 h time

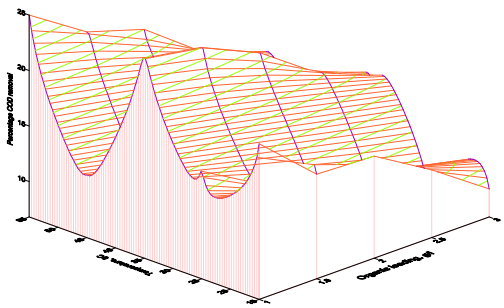

Fig. 8: Percentage COD removal under variable temperature and organic loading for 48 h time

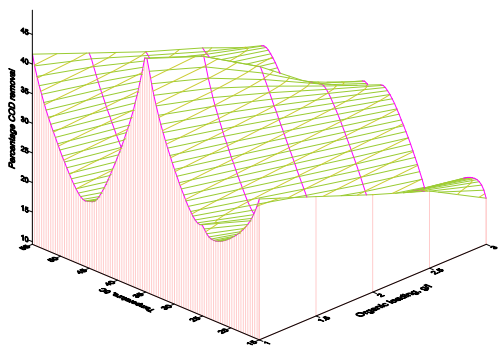

Fig. 9: Percentage COD removal under variable temperature and organic loading for 72 h time

C. Comparison in COD Removal Efficiency at Variable Temperature, Organic Loading and Time (with seeding)

Fig. 10 shows the percentage COD reduction in anaerobic treatment of synthetic milk wastewater at 15^0C constant temperature, in a batch operation. The values of COD clearly indicate that maximum percentage removal 54.16% takes place at lower organic loading 1g/l and maximum time 72h. However, a minimum removal of 41.33% has been observed at higher organic loading rate 3.0g/l and time, 72h. The reason may be more acclimatization period taken by anaerobic bacteria at higher organic loading as previously discussed. Additionally, the percentage COD reduction decreases with increase in organic loadings monotonically for different time periods. Fig. 11 shows the percentage COD reduction at 25^0C constant temperature, in a batch operation. The values of COD clearly show that maximum percentage removal 41.66% obtained at lower organic loading 1g/l and time, 72 h. However, a minimum removal of 28.00% has been observed at higher organic loading 3.0g/l and time, 72 h. Here also, the reason may be more acclimatization period taken by anaerobic bacteria at higher organic loading rates. The percentage COD reduction decreases with increase in organic loading rates monotonically for different time periods.

Fig. 12 illustrates the percentage COD reduction at 35^0C constant temperature, in a batch operation. The values of COD show that maximum percentage removal 83.33% observed at lower organic loadings 1g/l and time, 72 h. However, the minimum removal of 54.67% has been observed at higher organic loading 3.0g/l and time, 72 h. The reason may be same as previously described. The percentage COD reduction decreases with increase in organic loading rates but not monotonically for different time periods as in previous cases. The COD reduction at 24 h and 48h, time period follows different pattern than at 72 h time. However, at time 72 h, the trend of COD reduction follows the previous cases. Fig. 13 depicts the percentage COD reduction at 45^0C constant temperature, in a batch operation. The values of COD show that maximum percentage removal 33.33% observed at lower organic loadings 1g/l and time, 72 h. However, the minimum removal of 16.00% has been observed at higher organic loading 3.0g/l and time, 72 h. The reason may be similar to previously described. The percentage COD reduction decreases with increase in organic loading rates monotonically for different time periods as in previous cases. Fig. 14 illustrates the percentage COD reduction at 55^0C constant temperature, in a batch operation. The values of COD show that maximum percentage removal 62.50% observed at lower organic loadings 1g/l and time, 72h. However, a minimum removal of 41.333% has been observed at higher organic loading 3.0g/l and time, 72h. The reason may be same as previously described. The percentage COD reduction decreases with increase in organic loading rates monotonically for different time periods as in previous cases.

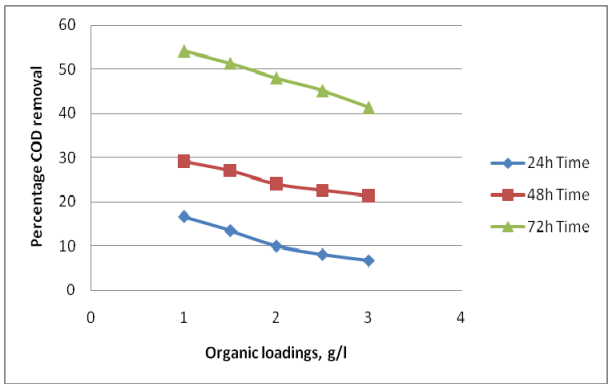

Fig. 10: % COD removal under variable organic loadings and time at 15^0C temperature

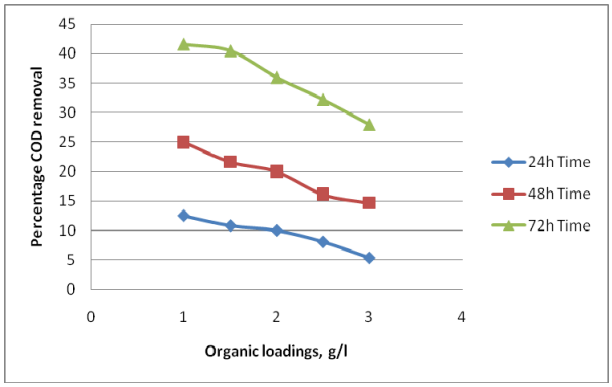

Fig. 11: % COD removal under variable organic loadings and time at 25^{0}C temperature

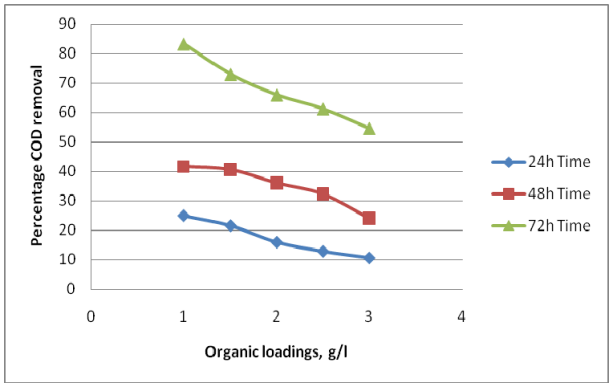

Fig. 12: % COD removal under variable organic loadings and time at 35^{0}C temperature

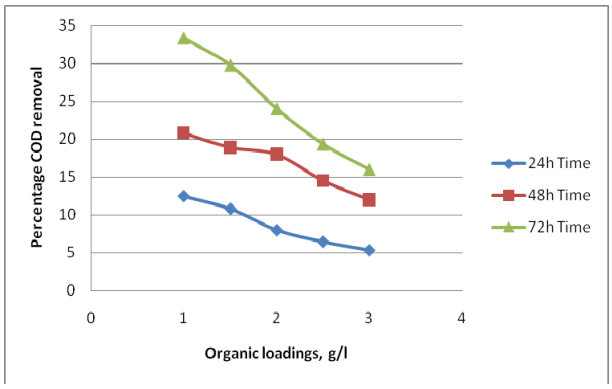

Fig. 13: % COD removal under variable organic loadings and time at 45^{0}C temperature

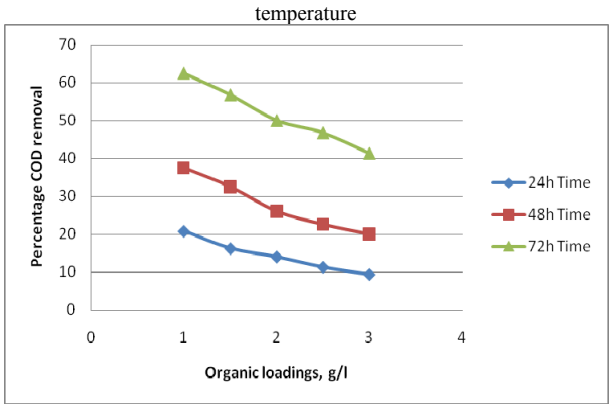

Fig. 14: % COD removal under variable organic loadings and time at 55^{0}C temperature

D. Comparison in COD removal efficiency at variable temperature, organic loading and time (with seeding)

Fig.15, Fig.16 and Fig 17 illustrate the three different peaks of percentage COD reduction at different temperature ranges i.e., psychrophilic (0 – 20^{0}C), mesophilic (20 – 42^{0}C) and thermophilic (42 – 75^{0}C) range, when milk wastewater has been treated with additional seeds. First peak of COD reduction lies on psychrophilic (0 – 20^{0}C) range, at which maximum COD removal takes place at 15^{0}C and thereafter, it decreases with increase in temperature till the end of psychrophilic range. The percentage COD reduction has also been obtained to be lesser at 25^{0}C because it lies at the initiation of mesophilic (20 – 42^{0}C) zone. The maximum percentage of COD reduction in this zone has been found to be at 35^{0}C temperature which is mid of mesophilic (20 – 42^{0}C) zone. Further, at 45^{0}C temperature, the percentage COD reduction has been found to be lesser than that of at 55^{0}C because is close to lower range of thermophilic zone. This may be due to efficient working of thermophilic microorganisms at 55^{0}C temperature. This three dimensional mesh view (Fig.15, Fig.16 and Fig 17) clearly indicates the effect of temperature and organic loading rates on percentage reduction of COD. They also give the intermediate values of COD reduction at various temperature levels and organic loading.

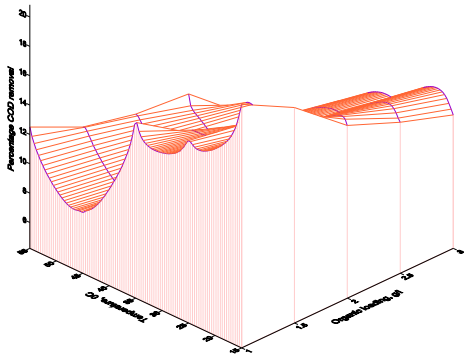

Fig. 15: Percentage COD removal at variable temperature and organic loading at 24 h time

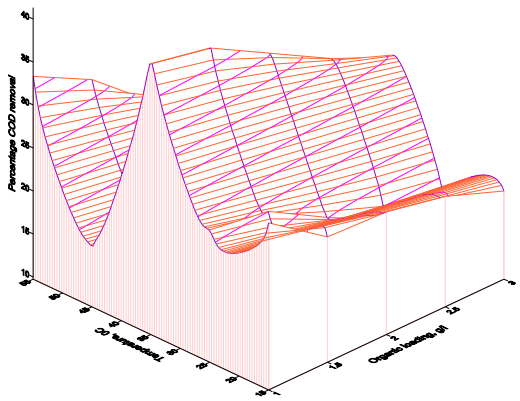

Fig. 16: Percentage COD removal at variable temperature and organic loading at 48 h time

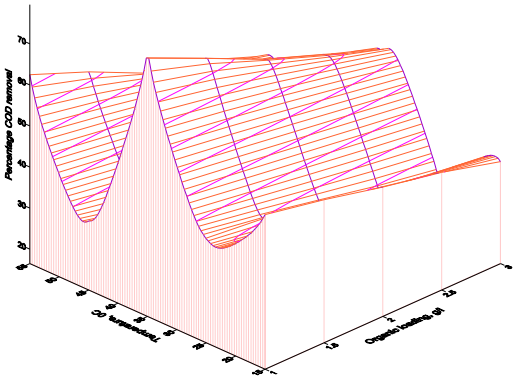

Fig. 17: Percentage COD removal at variable temperature and organic loading at 72 h time

V. CONCLUSION

Significant COD reduction at variable organic loadings, variable time periods and temperatures, with and without additional seeds for milk wastewater has been observed. The effluent initially changes to anaerobic mode in the first chamber and microorganisms are acclimatized. Thereafter, the waste is transferred to subsequent chambers and the reactor which acts as sequencing batch reactor. Experimental results show that this type of arrangement reduces the time of treatment and gives high treatment efficiencies. The percentage COD reduction increases with time period for all the cases considered in this study. The organic loading affects the COD reduction significantly. As organic loading increases, the percentage COD reduction decreases. This phenomenon has been observed in all the temperature ranges. The three different peaks of percentage COD reduction have been found out at different temperature ranges, i.e., psychrophilic, mesophilic and thermophilic ranges for both cases with and without providing additional seeds. The study finally concluded that the milk wastewaters may be treated efficiently at mid of all three temperature zones with and without providing additional seeds. The additional seeds improve the treatability and reduce the time of treatment because the same percentage of COD reduction may be obtained in less time period when additional seeds have been added. To sum up, without seeds, the maximum reduction of COD 50.00% has been observed at 35^0C, in a baffled batch reactor, at lower organic loading 1g/l and retention time of 72h. Whereas the COD reduction is 83.33% with additional seeds, under same conditions. This also suggests the presence of similar types of micro organism both in wastewater and seeding culture, except that the seeding culture was more acclimatized. Therefore, acclimatization of the culture media is recommended in such cases.

ACKNOWLEDGMENT

The author would like to acknowledge the technical assistance of the personnel and experts of the University School of Chemical Technology and the University School of Environmental Management, Guru Gobind Singh Indraprastha University, Delhi, India. Special thanks to Dr Kafeel Ahmad, Department of Environmental Engineering, Jamia Millia Islamia University, New Delhi, India.

REFERENCES

.

[1] Ramasamy, E.V., Gajalakshmi, S., Sanjeevi, R., Jithesh, M.N, Abbasi, S.A. (2004) Feasibility studies on the treatment of dairy wastewaters with upflow anaerobic sludge blanket reactors, Bioresour Technol 2004; 93: 209 – 212.

[2] Vidal G, Carvalho A, Mendez R, Lema JM. Influence of the content in fats and proteins on the anaerobic biodegradability of dairy wastewaters. Bioresour Technol 2000; 74:231–9.

[3] Demirel B, Yenigun O. and Onay, T.T. (2005) anaerobic treatment of dairy wastewaters: a review, Process Biochemistry, 2005: 40: 2583 – 2595.

[4] Suntud Sirianuntapiboona,*, Narumon Jeeyachokb, Rarintorn Larplaia,(2005) Sequencing batch reactor biofilm system for treatment of milk industry wastewater, a Division of Environmental Technology, School of Energy and Materials, King Mongkut's University of Technology Thonburi (KMUTT),Thungkru, Bangmod, Bangkok 10140, Thailand bDivision of Biochemical Technology, School of Bioresources and Technology, King Mongkut's University of Technology Thonburi,Thungkru, Bangmod, Bangkok 10140, Thailand, Journal of Environmental Management 76 (2005) 177–183

[5] A Mohseni Bandpi and H Bazari (2004) Biological treatment of dairy wastewater by sequencing batch reactor, Iranian J Env Health Sci. Engg., 2004 (01) pp. 65 – 69.

[6] S.H. Lin*, K.W. Cheng, A new sequencing batch reactor for treatment of municipal sewage wastewater for agricultural reuse, Department **of** Chemical Engineering, Yuan Ze University, Chungli, Taoyuan 320, Desalination 133 (2001) 41-51.

[7] Wang, J., Huang, Y. and Zhao, X. (2004) Performance and characteristics of an anaerobic baffled reactor, Bioresource Technology, 93 (204) 205 – 208.

[8] A.J.Cavaleiro$_1$,M.M. Alves$_2$, Biosorption and mineralization of a dairy wastewater under sequential operation mode ,[1]CERNAS, Dpt. Biologia e Ecologia, Escola Superior Agrária de Coimbra, Bencanta, 3040-316 Coimbra, Portugal, [2]Centro de Engenharia Biológica, Universidade do Minho, Campus de Gualtar, 4710-057 Braga, Portugal.

[9] Wisaam S.A.R., He Qiang and Wei Wu Qiang (2007) Review on sequencing batch reactors, Pakistan Journal of Nutrition, 6(1): 11-19, 2007.

[10] Veysel Eroglu, Izzet Ozturk, Ibrahim Demir, Lutfi Akca and Kadir Alp (1992) Proceedings, 46th Purdue Industrial waste Conference, Lewis Publishers Inc., Chelses, Michigan, USA.

[11] Banik GC, Dague RR. ASBR treatment of low strength industrial wastewater at psychrophilic temperatures. Water Sic Technol 1997; 36:337–44.

[12] Dugba P, Zhang R. Treatment of dairy wastewater with two-stage anaerobic sequencing batch reactor systems—thermophilic versus mesophilic operations. Bioresour Technol 1999; 68:225–33.

[13] Ruiz C, Torrijos M, Sousbie P, Martinez JL, Moletta R. The anaerobic SBR process: basic principles for design and automation. Water Sci. Technol 2001; 43:201–8.

[14] Venkata Mohan, S., Lalit Babu, V., Sarma, P.N. Anaerobic biohydrogen production from dairy wastewater treatment in sequencing batch reactor: Effect of organic loading rate, Enzyme and Microbial Technology, 41 (2007) 506 -515.

[15] Sinan UYANIK, A Novel Anaerobic Reactor: Split Fed Anaerobic Baffled Reactor, Environmental Engineering Group, Engineering Faculty, Harran University, Sanhurfa-Turkey, Turkish J. Eng. Env. Sci. , 27 (2003) , 339 - 345.

[16] Mark J. hammer (1977) Water and wastewater technology, published by John Wiley and Sons, New York, USA.

[17] Wilson Parawira (2004) Anaerobic Treatment of Agricultural Residues and Wastewater: Application of High-Rate Reactors, PhD thesis, Department of Biotechnology, Lund University.

[18] World Bank Group, Dairy Industry, Pollution Prevention and Abatement Handbook, July 1998.