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Applications of Sequencing Batch Reactor in the Degradation of Dairy Industry Wastewater

S. Sivaprakasam, K.Balaji

Abstract: ***Biodegradation using sequencing batch reactor is one of the best method of treating the wastewater from the diary industries. Milk and milk based products has become most essential and important role in day-to-day life of human. The raw milk undergoes various processing in dairy industries to produce other milk based products. The large quantities of water and other chemicals are required in a diary plant. The volume of water used in a diary industry varies with respect to the availability of water, processing method and type of flow. The waste water after every step of processing is discharged into either the natural water bodies or to the environment which alters the ecological balance. This research work on the laboratory scale model is used for the analysis and treatment of dairy industry wastewater. The parameters studied are the biological oxygen demand, chemical oxygen demand, dissolved oxygen, total dissolved solids, suspended solids, pH and other substances present in the diary waste water. In this study, biodegradation of dairy wastewater was investigated under a sequencing batch reactor under aerobic conditions. It is performed on three different phases with variable reaction time to study the reductions in BOD, COD and other parameters respectively.***

Index Terms: Sequencing Batch Reactor, Biological Treatment, Dairy Wastewater, Biodegradation.

I. INTRODUCTION

Milk is considered to be one of the most important commodities and need for the healthy life of human. The dairy industry is characterized by the large number of products like pasteurized milk, cheese, butter, condensed milk, yoghurt, ice cream, panneer, milk powder, etc. are also produced. The waste water from the dairy industry is mostly white in color, little alkaline in nature and turns acidic when it is fermented. The effluent coming out of a diary industry largely contains organic substances and suspended solids. The substances that are present in this waste liquor are the most responsible for the increase in biological oxygen demand (BOD) and chemical oxygen demand (COD). There is also more suspended matter present in the content of diary waste and it is significant mainly due to fine curd found in cheese waste. The pollution effect of dairy waste is attributed to the immediate and high oxygen demand. Milk treatment and processing is the set of sequential steps involving the preparation of raw milk by heat treatment as a preliminary procedure before milk processing.

The waste water generated from the dairy industries includes large quantities of milk constituents like casein, inorganic components, detergents and sanitizers used for washing. It has high sodium content from the use of caustic soda for cleaning. Casein is a milk phosphoprotein which is found abundant in the milk of all the mammals. It is also found in the other dairy products produced from milk. Presence of casein in the milk processed waste water will get deteriorate and lead to the formation of intense sludge and produce strong odors polluting the environment. In addition to these types of substances, the waste water from the diary industry also characterized from the parameters like temperature, pH, color, BOD, COD, dissolved solids, suspended solids, DO, chlorides, sulphate, oil & grease and other inorganic substances.

Sequencing Batch Reactors (SBR) also called as sequential batch reactors are one among the important type of reactors in the treatment of industrial wastewater in the processing tanks. Early researchers handled the biological degradation method using activated sludge system operating with a procedure of “fill and draw” process. This “fill and draw” process involved in the treatment methods paved way to establish a technology called SBR. The high BOD and COD of the industrial waste water were greatly reduced by this application of SBR to make suitable for discharge into sewers or for use on land. The SBR is also used to treat other industrial waste water like waste water from piggery industry. Obaja et al. 2005 studied about the biological nutrient removal with SBR using an internal organic carbon source in digested piggery wastewater and obtained an efficiency of 99.8% removal of nitrogen and 97.8% of phosphate (Obaja et al. 2005). Ling and Lo, 1999 carried out some experiments on the treatment of brewery wastewaters with a laboratory-scale sequencing batch reactors under aerobic condition and demonstrated that brewery wastewater can also be treated efficiently with a reduction of over 90% of TOC (total organic carbon), BOD5, COD, and SS (suspended solids) (Ling and Lo, 1999). Similarly the SBR was also tested for the post treatment process of brewery wastewater by Rodrigues et al. 2001 and found that SBR has the capable of removing the environmental parameters nearly 97% (Rodrigues et al. 2001). The biological treatment of many industrial wastewaters is found to be successful by sequencing batch reactor (SBR). It operates on sequence of steps like fill, react, settle, draw and idle to treat the waste water in defined period of time. Apart from the treatment of diary industrial wastewater, it is also used to treat the various other effluents from textile, brewery, tannery, petrochemical, paper and pulp, pharmaceutical, poultry.

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***** Correspondence Author

S.Sivaprakasam*, Assistant Professor, Department of Civil Engineering, Government College of Engineering, Dharmapuri, Tamil Nadu, India.

K.Balaji, Assistant Professor, Department of Civil Engineering , Anna University, Panruti Campus.Cuddalore District.Tamilnadu,India.

Treatment of different industrial wastewater using SBR is found to be a successful for its low cost, high efficient and flexible operating technology and also mainly because of its customized fabrication and design and automation. SBR operated on different sequence of equalization, neutralization, biological treatments and secondary clarification in a single tank using at a timed control sequence. The use of SBR technology was found to exist since 1920 in various other parts of the world. It received a greater attention and it is widely used in USA, Europe and China to treat their waste waters from the industries and municipalities. SBR is suitable particularly where the system has a different flow patterns and access of automation technology. The objective of this study in treating dairy waste water is to reduce the high biological oxygen demand (BOD), chemical oxygen demand (COD), oil, grease and other parameters to values much lesser than the permissible limits.

III.MATERIALS AND METHODS

A. Sample Procurement:

The effluent was collected at the outlet of settling tank from Hatson Dairy Industry. The effluents were collected in a closed plastic tank with a volume of 50 L and the same is refrigerated at 4°C for further studies. The collected raw waste water from the diary industry was analyzed for pH, COD, BOD, TS, TDS, TSS by the respective standard methods. The characteristics of dairy effluent was analyzed and given in the table 1.

Table 1: Characteristics of dairy waste water and synthetic waste water

S.No.	Parameters	Dairy waste water
1.	pH	5.1
2.	Turbidity (NTU)	723
3.	BOD (mg/L)	1150
4.	COD (mg/L)	2500
5.	Conductivity (mS)	3.12
6.	Colour	Colorless
7.	Salinity (ppt)	1.2
8.	Sulphate (mg/L)	74
9.	Chlorides (mg/L)	227
10.	Oil and grease (g/L)	1.2
11.	TDS (mg/L)	16
12.	TSS (mg/L)	10
13.	Total solids (mg/L)	26

B. Physico-chemical analysis

In this study of treatment of industrial dairy waste water, physical parameter such as pH, Temperature, TDS and chemical parameters namely COD, BOD, Sulphates, Chloride, Oil and Grease are the physico – chemical parameters of the dairy waste water were measured. A Water Analyzer Kit (Systronics Water Analyzer 371) was used to determine the above parameters. BOD and COD were estimated by titration method and reflux method respectively, while the presence of chlorides was estimated using Mohr's Method.

IV. EXPERIMENTAL DESIGN

The batch studies on the treatment of dairy industry waste water was carried out in a fabricated reactor which is transparent and made of poly acrylic sheets in square shape with a cross sectional area of 20 cm x 20 cm x 20 cm, a total volume of 8 liter and a working volume of 6 liter (20 cm x 20 cm x 15 cm). The working volume of reactor was fixed based two factors, one the height of the fill line considered for the treatment of dairy wastewater and two the space required for the effluent rise during the agitation. The reactor was fixed with agitating set up using an air pump. A perforated pipe was immersed into the reactor and it is connected to air pump. After the fabrication of SBR it is operated for a period of time to get microbe acclimatization. SBR was operated on a cycle per day with dairy wastewater as feed. One cycle is operation of the reactor for particular period of time (5, 6, 7, 8, 9, 10 hours cycles).

Table: 2 Time of operation of the SBR on each stage in each cycle

S. No	Stages	Time of Operation at each stage (minutes)					
		5 Hr Cycle	6 Hr Cycle	7 Hr Cycle	8 Hr Cycle	9 Hr Cycle	10 Hr Cycle
1.	Fill (20%)	60	72	84	96	108	120
2.	React (30%)	90	108	126	144	162	180
3.	Settle (30%)	90	108	126	144	162	180
4.	Draw (10%)	30	36	42	48	54	60
5.	Idle (10%)	30	36	42	48	54	60
Total (100%)		**300**	**360**	**420**	**480**	**540**	**600**

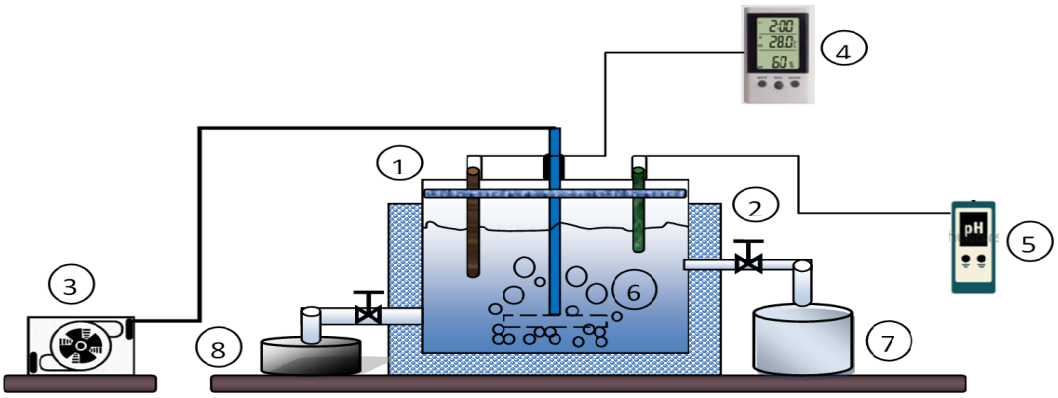

Figure: 1 Schematic diagram of the fabricated laboratory SBR system

(1) Reactor (2) Outer water bath (3) Air Pump (4) Temperature Probe (5) pH Probe (6) Perforated pipe (7) Supernatant Liquid Tank (8) Sludge Collector

IV. RESULTS AND DISCUSSION

Experimentation for the treatment of industrial diary waste water (IDWW) was carried out in the SBR fabricated with transparent acrylic sheets as mentioned and schematically shown in Fig.1. SBR is activated for the microbial acclimatization for a period of time with municipal waste water. The SBR was operated on one cycle per (with fixed time) day with industrial dairy wastewater as feed. One cycle is considered as the period of operation of the reactor at a fixed duration of time (5, 6, 7, 8, 9, 10 hours cycles). The efficiency of the SBR in treating the IDWW was studied and compared simultaneously.

The operating sequence of the SBR is by conducting the experimentation in different stages with different modes of reaction namely fill, react, settle, draw and idle. The efficiency of the reactor can be achieved by optimizing the duration of reaction at each stage (Hisset et al. 1982). The time of operation or the duration of the reaction is fixed as 20% fill, 30% react, 30% settle, 10% draw and 10% idle on each cycle. The time of operation of the SBR on each stage in each cycle is given in table 2.

Table: 3 Values of the parameters at each cycle

Cycles (in Hr)	% BOD Reduction	% COD Reduction	TDS	TSS	pH	Turbidity
5	72.52	66.52	1.1	2.1	6.4	101.2
6	76.09	71.13	0.98	1.9	6.6	86.9
7	80.43	75.73	0.96	1.6	6.9	83.5
8	81.74	77.82	0.94	1.4	7.2	79.2
9	83.48	80.17	0.91	1.2	7.3	78.5
10	84.78	81.30	0.87	1.1	7.5	77.4

In stage 1 the operation of reactor in the first cycle (5 hr) consists of 60 min of fill, 90 min of react, 90 min of settle, 30 min of draw and 30 min of idle. The performance of the SBR was analyzed by measuring the parameters of the diary industry waste water like pH, % BOD reduction, % COD reduction, total dissolved solids, total solids and turbidity. In which the BOD was found to be reduced and the percentage of BOD reduction is 72.5. Similarly the other parameters were also found to be reduced. The COD of the 5 hr cycle was found have a reduction of 66.52%. The total dissolved solids present in the waste water after the 5 hr cycle was 1.1 mg/L and the total suspended solids were found to be 2.1 mg/L. The change in pH was also measured after the operation of SBR for 5 hr cycle and it was found to be 6.4. The turbidity is also one of the important parameter to be characterizing the industrial waste water and it found to be 101.2. Similarly in stage 2 the operation of reactor in the second cycle (6 hr) consists of 72 min of fill, 108 min of react, 108 min of settle, 36 min of draw and 36 min of idle. The performance of the SBR was analyzed for the above set of cycle by measuring the same parameters of the diary industry waste water. In which the percentage of BOD reduction is 76.1. Similarly the other parameters were also found to be reduced. The COD of the 6 hr cycle was found have a reduction of 71.13%. The total dissolved solids present in the waste water after the 6 hr cycle was 0.98 mg/L and the total suspended solids were found to be 1.9 mg/L. The change in pH was also measured after the operation of SBR for 6 hr cycle and it was found to increase a little to a value of 6.6. The turbidity of the industrial waste water after the 6 hr cycle in SBR found to be 86.9.

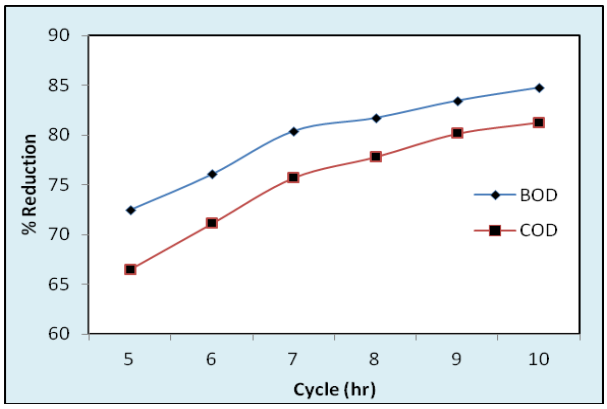

Figure 2. % reduction of BOD and COD in each cycle operation of SBR

As the values of the characterizing parameters of the industrial diary waste after was found to get decreased after increasing the time of the cycle, the operation of reactor is proceeded to the fourth cycle (8 hr) consists of 84 min of fill, 126 min of react, 126 min of settle, 42 min of draw and 42 min of idle. Similarly the performance of the SBR in reducing the values of the industrial diary waste water was analyzed for the above set of cycle by measuring the characterizing parameters of the diary industry waste water. In which the percentage of BOD reduction is 80.43. The COD after the 7 hr cycle was found have a reduction of 75.7%. The total dissolved solids present in the waste water after the 7 hr cycle was 0.96 mg/L and the total suspended solids were found to be 1.6 mg/L. The change in pH was also measured after the operation of SBR for 7 hr cycle and it was found to increase a little to a value of 6.9. The turbidity of the industrial waste water after the 7 hr cycle in SBR found to be 83.5.

The operation of reactor in the third cycle (8 hr) consists of 96 min of fill, 144 min of react, 144 min of settle, 48 min of draw and 48 min of idle. In which the percentage of BOD reduction is 81.74. The COD after the 8 hr cycle was found have a reduction of 77.8%. The total dissolved solids present in the waste water after the 8 hr cycle was 0.94 mg/L and the total suspended solids were found to be 1.4 mg/L. The change in pH was also measured after the operation of SBR for 8 hr cycle and it was found to increase a little to a value of 7.2. The turbidity of the industrial waste water after the 8 hr cycle in SBR found to be 79.2.

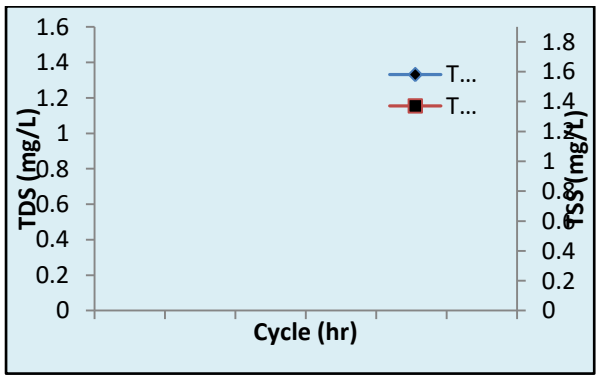

Figure 3. % reduction of TDS and TSS in each cycle operation of SBR3

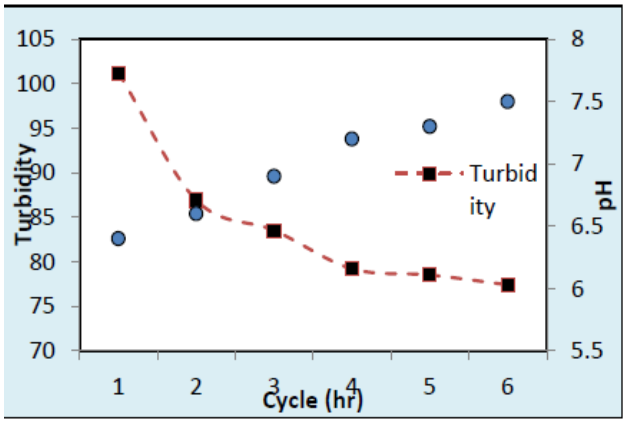

Figure 4. % reduction of TDS and TSS in each cycle operation of SBR

As the efficiency of the SBR was found to be increasing with the increase in the reaction time the values of the characterizing parameters of the industrial diary waste water was found to be decrease. So further the time of the cycle and the operation of reactor are proceeded to the fifth cycle (9 hr) and sixth cycle (10 hr) consists of different set of period of operation at each stage contributing to a predominant reduction of the environmental parameters. The percentage of BOD reduction is 83.5 and 84.8 in their respective cycles. Similarly the reduction of COD after the 9 hr cycle and 10 hr cycle were found to be 80.2 and 81.3% respectively. The complete change in the percentage of reduction in BOD and COD in treatment of industrial dairy waste water is represented in Fig. 2. The total dissolved solids present in the waste water after the 9th and 10th hr cycle were 0.91 and 0.87 mg/L respectively and the total suspended solids on both the cycles were found to be 1.2 and 1.1 mg/L (Fig.3). The pH measured at both 9 hr cycle and 10 hr cycle did not vary much and turned slightly base to a value of 7.5 (Fig.4). The turbidity of the waste water treated for 9 hr and 10 hr cycle reduced to a greater extent of 77.4 (Fig.4). Li et al, (2002) experimented a single-stage SBR system with an influent COD of 10,000 mg/L at three stages of different hydraulic retention times (HRTs) of 1, 2, and 3 days and also with an influent COD value of 20,000 mg/L at four stages of different HRTs of 1, 2, 3, and 4 days. In which, it was proved that HRT of 1-day was found to be more sufficient and efficient for treating the industrial dairy waste water with a removal efficiency of 80.2% reduction in COD, 63.4% reduction in total solids, 66.2% reduction of volatile solids, 75% reduction in total Kjeldahl nitrogen, and 38.3% total nitrogen from the liquid effluent (Li et al. 2002). Bandpi et al. 2004 published the results obtained from the studies conducted in the treatment of industrial dairy waste water using SBR was found to be more efficient and predominant that the SBR was a much suitable alternative for the treatment of industrial dairy wastewater with a maximum removal efficiency of 90% COD (Bandpi et al. 2004).

The application of SBR technology to treat the waste water from the cheese plant is exceptionally suitable and found to be very effective with a removal of 97.7% total COD and 99.8% BOD5 (Torrijos et al.2001). Mohseni and Bazari, 2004 investigated the possibility of treating wastewater from a milk factory using a fabricated bench-scale SBR and succeeded by reducing the COD more than 90% (Mohseni and Bazari, 2004). Samkutty et al. [6] studied biological treatment of dairy plant wastewater with SBR. Significant percentage of reductions of some parameters were obtained (97% BOD, 93% COD, 97% TSS, 76% TS) in the biological treatment of Dairy waste water using SBR by Samkutty et al. 1996. The efficiency of SBR in the treatment of wastewater from a dairy plant was experimented and published by Mohamed and Saed, 1995. The sequence of operation and the duration on the each phase followed by the SBR system consisted of a 30-min aeration feed, 12-h reaction with O2, 1-h settling period without O2, 30-min draw without O2, and 15-min idle phase. With this sequence of cycle and period, Mohamed and Saed, 1995 achieved a reduction of 96.7% of NH3-N, 94% of COD, and 96% of SS. According to the United States Environmental Protection Agency Office of Water Washington, D.C, the performance of SBRs is typically comparable to conventional activated sludge systems and depends on system design and site specific criteria.

Depending on their mode of operation, SBRs can achieve good BOD and nutrient removal. For SBRs, the BOD removal efficiency is generally 85 to 95 percent.

V.CONCLUSIONS

In the present study the efficiency and applicability of the SBR was tested to treat the raw waste water of a diary industry. The reactor was operated at different stages with different set hydraulic retention time. In which it was found that the increase in the time of operation at each stage increased the efficiency of reducing the values of characterizing parameters like BOD, COD, pH, TDS, TSS and turbidity of dairy industry waste water the reactor. A maximum BOD reduction of 84.8%, COD reduction of 81.3% and a minimum 0.87 and 1.1 mg/L of TDS and TSS was achieved at the operation of SBR at 10 hr cycle. From this study it is evident that the SBR was found to be an efficient, simple and cost effective reactor to treat the diary industry waste water.

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