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Efficiency Assessment of Combined Treatment Technologies: A Case Study of Charminar Brewery Wastewater Treatment Plant

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ABSTRACT

Present research study was conducted for a period of one year focusing and closely studying each and every phase of charminar brewery industry wastewater treatment process as a cumulative research. This study is relevant to the large scale operations including all wastewater treatment steps and their efficiencies of treatment in terms of physicochemical point of view. The full length study starts from untreated wastewater followed by anaerobic treatment and its performance, aerobic treatment and its pollutant removal ability, ultrafiltration- its sieving capacity and reverse osmosis- its solution diffusion ability. Anaerobic, aerobic and reverse osmosis shows high COD and BOD removal efficiency where as ultrafiltration shows less organic removal. Ultrafiltration gives TSS free water, aerobic treatment has 58.0 to 97.9% TSS removal whereas anaerobic phase has poor TSS removal capacity. The reverse osmosis gives better removal efficiency of COD (70.0 to 90.1%), TDS (90.5 to 94.2%) and BOD (77.7 to 80.0%).

Key Words: Anaerobic treatment, Aerobic treatment, Ultrafiltration, Reverse osmosis, Brewery wastewater, Efficiency.

INTRODUCTION

As we know brewing business is an important business in food industry, in economic and employment stand point of view in the world. Water plays a significant role in the entire process performance of brewing industry (Moll and Bieres 1991; Luc *et al.*, 2006; Perry and De Villiers 2003). The average water consumption for wastewater-management-disposal has become ever more significant in present day's context not only in profitable view but also in environmental point of view Luc et al., (2006) ; Perry and De Villiers (2003) ; Kunwar *et al.,* (2004) ; Siret (2001) ; Teresa and Carlos (2001). In the process brewing, two-third of water is used for production of beer and one-third of water is used for washing of floors, cleaning the brew house, cellars, packing and cleaning for each batch Moll et al., (1991). Throughout every year, Charminar Brewery Industry in Hyderabad - India uses large volumes of water for production and discharges large volumes of effluent. Due to this highly effluent which contains high organic and acidic content, which results in increase of biological oxygen demand (BOD) and chemical oxygen demand (COD) and high organic load in the wastewater results from dissolved carbohydrates, alcohol, suspended solids, yeast etc, which has potential to cause considerable environmental problems in polluting lake ecology and leads to low efficiency of municipal treatment works Zvaura et al., (1994); Kilani (1993). In order to control pollution and protect the environment, brewery effluent containing high concentrations of organic matter should not be discharged to watercourses. The Andhra Pradesh Pollution Control Board (APPCB) is placing stringent restrictions on the quality of effluents which industry can discharge into the environment, this makes on-site pretreatment mandatory for some types of effluent every phase of wastewater treatment in brewery industry has its own significance. Many research studies have been conducted that focused on a singular brewery wastewater treatment phase. However, this present research study focused on the entire treatment phases as a cumulative efficiency assessment study in the brewery industrial wastewater treatment plant.

MATERIALS AND METHODS

Charminar breweries effluent treatment plant (ETP) is located at Hyderabad, Andhra Pradesh, India. The plant lay out is shown in Figure 1. The effluent treatment plant consists of: collection tank (CT), screening chambers (0.5 mm mesh), equalization (neutralization) tank (ET), primary clarifier (PC), buffer tank (BT), up flow anaerobic sludge blanket (UASBR), gas chamber (GC), flare foundation (F) aeration tank-1(AT-1), clarifier-1 (CF-1), aeration tank-2 (AT-2), clarifier-2 (CF-2), clarifier-3 (CF-3), monobelt sludge dewatering press (MSDP), multi grade filter (MGF), activated carbon filter (ACF), ultra filtration (UF), reverse osmosis (RO-1), reverse osmosis (RO-2),solar pond evaporation system (SPES), treated water tank (TWT), sludge drying beds (SDB) and lagoon.

Present research study was conducted for a period of one year, the wastewater samples were collected by grab sampling method using sterile one liter plastic containers. Samples were collected in pre-sterilized bottles from equalization tank, primary clarifier, buffer tank, up flow anaerobic sludge blanket, Aeration tank-1, Clarifier-1,Aeration tank -2, Clarifier-2, Clarifier-3, multi grade filters, activated carbon filter, ultra filtration, Reverse osmosis-1, Reverse osmosis-2, for physicochemical analyses (ph, Temperature, COD, BOD, alkalinity, volatile fatty acids, MLSS, TSS, TDS, DO and hardness). All samples were transported to the laboratory and analyzed within 30 min. All parameters were analyzed in accordance with standard methods American Public Health Association (1993). The operating conditions of effluent treatment plant are summarized in Table 1.

RESULTS AND DISCUSSION

Equalization Tank

The equalization tank pH ranges from 3.2 to 10.7. In brewing the quantity and the quality of the effluent may vary from hour to hour. The physicochemical analysis of anaerobic treatment is presented in Table 2. In equalization tank mechanical aerators provide aeration. Equalization tanks are 01A and 01B each with 500 kl capacity. These spacious tanks are suitable for proper mixing and avoid any kind of overflow. Sometimes the solids were choking in the aeration pumps which are causing blocking of the pumps. The COD ranges from 4000 to 14400 mg/L. The primary clarifier has 420 kl capacity. The pH is 4.6-8.4. These solids are pumped to the sludge drying beds (SDB). Due to the removal of settlable solids the COD range decreases to 4320 to 7840 mg/L. Improper separations of settlable solids are choking the feed line and increase the false TSS in the UASBR. The buffer tank pH is 6.2 to 8.1. In the buffer tank part of the UASBR effluent is mixed with raw effluent for pre-acidification. The pH is optimized around 6.2 to 8.1 by using dosing system.

UASBR

The UASBR pH ranges from 7.2 to 7.6. The best treatment was observed below 40°C. Alkalinity and volatile fatty acids showed considerable effect on UASBR process, the alkalinity and volatile fatty acids ratio was 2:1. Gas liquid solid separator is located at the top of the UASBR, this collects the biogas which burns in the flame. UASBR performance was monitored using TSS profile indication results of port samples which specify whether proper sludge blanket is formed. The UASBR was efficient in removal of COD (78.7 to 93.7%) and BOD (73.3 to 94.7%). UASBR has less activity on TSS and TDS.

COD removal efficiency from USABR was compared with sugarcane wastewater which showed 70-85% (Bing-Jie et al., 2009) whereas Valeria et al., (2008) reported 69.68% in distillery wastewater, Jain-hui *et al.*, (2009) and Buzzini and Pires (2007) published 81.1, 78% respectively in pulp industry, Fakhru Razi (1994) and Garcia *et al*., (2008) 85, 70% respectively in slaughterhouse wastewater, Rajkumar et al., (2010) reported 83.4% in dairy units whereas Xiangwen et al.,(2008), Leal et al., (1998), Mario et al., (1999) and Ahn et al., (2001) reported 90, 96, 73, 80% respectively in brewery wastewater

Aeration Process

The complete aeration treatment process is summarized in the Table 3 which shows the minimum and maximum values of the tested physicochemical parameters. Each aeration tank contained ten aeration blowers. The pH ranged from 7.6 to 8.6. TSS, COD and BOD values gradually decreased from Aeration tank-1 to Clarifier-3.The amount of dissolved oxygen was raised from 0.2 to 4.8 mg/L. The MLSS ranged from 340 to 990 mg/L. COD removal was from 62.5 to 91.6%, BOD from 75.0 to 90.0% and TSS from 58.0 to 97.9% whereas it has less effect on TDS (from 3.2 to 21.3%). Poor bacterial settling was observed at temperatures greater than 37°C which resulted decrease in treatment efficiency (Carpenter *et al.*, 2000). The best BOD removal at 35°C (that is, below thermophilic temperatures) was observed in aeration process when compared to municipal or industrial wastewater (Duke et al., 1991).

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Table 1. Operational details of effluent treatment plant.

		Capacity	Feed flow (m^3/h)	Product Flow (m^3/h)	Reject flow (m^3/h)	Inlet pressure (kg/cm^2)	Outlet pressure (kg/cm^2)	Feed pressure (kg/cm^2)	Brine pressure (kg/cm^2)
Equalization tank 1+1		500+500m^3	55.0	50.0	-	-	-	-	-
Primary clarifier		420 m^3	50.0	38.0	-	-	-	-	-
Buffer tank		216 m^3	38.0	36.0	-	-	-	-	-
UASBR		2400 m^3	36.0	30.0	-	-	-	-	-
Aerationtank-1		1100 m^3	30.0	30.0	-	-	-	-	-
Clarifier-1		400 m^3	30.0	30.0	-	-	-	-	-
Aerationtank-2		900 m^3	30.0	30.0	-	-	-	-	-
Clarifier- 2		275 m^3	30.0	30.0	-	-	-	-	-
Clarifier-3		110 m^3	30.0	30.0	-	-	-	-	-
MGF		40 m^3/h	37.0	-	-	1.8	1.6	-	-
UF		35 m^3/h	-	-	3.2	1.2	0.8	-	-
RO-1		30 m^3/h	-	18.0	6.5	2.8	-	15.0	13.5
	MGF	40 m^3/h	25.0	-	-	2.1	1.9	-	-
RO-2	Permeate Water	30 m^3/h	-	16.0	8.5	-	-	15.0	14.0
	Reject Water	-	-	16.0	8.5	-	-	14.5	14.0
Solar pond Evaporating system		180 m^3/day	-	-	-	-	-	-	-
Treated water tank		200 m^3	-	-	-	-	-	-	-

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Table 2. Physicochemical analysis of brewery wastewater treated by UASBR.

Parameter	Range of Values in Equalization Tank	Primary Clarifier Outlet	Buffer Tank Outlet	UASBR Outlet	UASBR Port Samples				
					Port-1	Port-2	Port-3	Port-4	Port-5
Ph	3.2-10.7	4.6-8.4	6.2-8.1	7.2-7.6	6.6-7.4	6.6-7.4	6.6-7.4	6.6-7.4	6.6-7.4
COD (mg/l)	4,000-14,400	4320-7840	2560-7040	160-1600	-	-	-	-	-
Total Suspended Solids (mg/l)	2280-6200	2148-5834	2014-5632	1650-4820	3400-37,820	3680-26,700	3540-27,380	3260-25,184	120-22,240
Total Dissolved Solids (mg/l)	2260-4600	2341-4532	1802-3864	1530-2924	-	-	-	-	-
Temperature (^oC)	25-42	25-42	25-42	25-42	25-42	25-42	25-42	25-42	25-42
Alkalinity (mg/l)	620-1420	580-1380	630-1400	690-1580	-	-	-	-	-
BOD (mg/l)	2600-7800	2500-4700	1536-4500	80-1200	-	-	-	-	-
Volatile fatty Acids (mg/l)	93-8014	96-8100	100-8605	1671-9462	6890-9462	4281-7461	3481-6846	2618-4865	1671-2300
Volatile Suspended Solids (mg/l)	-	-	-	-	2820-16,100	2200-12,120	2600-15,720	2180-13,180	980-6780

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Table 3. Physicochemical analysis of brewery wastewater by aerobic process.

Parameter	**Aerationtank-1**	**Clarifier-1**	**Aerationtank-2**	**Clarifier-2**	**Clarifier-3**
Ph	7.6-8.2	7.6-8.2	8.0-8.6	8.0-8.5	8.2-8.4
Temperature (^{o}C)	25-42	25-42	25-42	25-42	25-42
COD (mg/l)	-	160-1120	-	120-480	60-133
BOD (mg/l)	-	130-680	-	70-240	20-120
DO (mg/l)	-	0.2-1.2	-	1.3-4.2	1.2-4.8
Total Suspended Solids (mg/l)	-	2400-4600	-	1760-2260	34-2020
Total Dissolved Solids (mg/l)	-	900-2800	-	900-2250	1600-2300
Mixed Liquor Suspended Solids (mg/l)	340-990	-	350-930	-	-

Table 4. Pollutants efficiency removal by UF and RO.

				RO-1		RO-2	
Parameter	**MGF outlet**	**ACF outlet**	**UF Outlet**	**Outlet**	**Reject**	**Outlet**	**Reject**
Ph	7.4-7.7	7.5-7.9	7.4-7.7	6.8-7.2	5.6-6.5	6.4-6.7	6.3-6.6
Temperature (°C)	27-34	27-34	27-34	27-34	27-34	27-34	27-34
Total dissolved solids (mg/L)	1850-2200	1200-1870	1400-2200	100-260	2200-7000	80-190	7000-20000
Hardness(mg/L)	220-320	220-320	220-320	6-22	200-500	4-12	340-720
Total suspended solids (mg/L)	20-70	20-50	Nil	Nil	Nil	Nil	Nil
(mg/L)	110-220	40-80	20-60	2-16	250-520	2-8	320-800
BOD (mg/L)	10-40	10-40	10-36	1-6	50-120	2-8	50-300
Turbidity (ntu)	10-20	4-8	1-4	Nil	1-3	Nil	1-2

Table 5. Efficiency of brewery wastewater treated by combined technology.

Parameter	**Anaerobic treatment Efficiency (%)**	**Aerobic treatment Efficiency (%)**	**Ultrafiltration efficiency (%)**	**Reverse osmosis Efficiency (%)**
COD (mg/l)	**78.7-93.7**	**62.5-91.6**	**54.8-66.6**	**70.0-90.1**
Total suspended Solids (mg/l)	**14.4-18.7**	**58.0-97.9**	**100**	**-**
Total dissolved solids (mg/l)	**15.0-24.3**	**3.2-21.3**	**12.5-13.0**	**90.5-94.2**
BOD (mg/l)	**73.3-94.7**	**75.0-90.0**	**50.0-70.2**	**77.7-80.0**

Clarifiers 1, 2 and 3 were connected with monobelt sludge dewatering press. Through this system 70% sludge cake was formed which was used as bio-fertilizer and the same was reported by Kanagachandran and Jayaratne (2006) for sugarcane sludge. The excess amount of sludge in primary clarifier (and Clarifiers 1, 2 and 3) was drained into sludge drying beds (SDB). Excess amount in Clarifier-3 was drained into lagoons (which are five in number). However Bodalo et al., (2003) reported 97% COD removal where as Shu-Guang et al., (1994) ; Zhou and Daniel (2001); Abdessemed et al., (2000) 85%. The reverse osmosis gave better removal efficiency of COD (70.0 to 90.1%), TDS (90.5 to 94.2%) and BOD (77.7 to 80.0%) when compared with previous results by Van Hoof et al., (1999); Zanfang et al., (2010); Slater et al., (1983); and Sadr et al., (2003). RO-1 and RO-2 outlet water is collected in treated water tank (capacity 200 kl), this water is used for washing of floors and cleaning the brew house, cellars, packaging, cleaning for each batch and gardening. The RO-2 reject water is collected in solar pond evaporation system (SPES) capacity 180 kl/day which is used for evaporate water and rest settleable substance forms sludge cake. The combined treatment efficiency of various treatment technologies is mentioned in the Table 5.

This study investigated the treatment efficiency of brewery wastewater treated in phases the anaerobic, aerobic and reverses osmosis shows high COD and BOD removal efficiency where as ultra filtration showed less organic removal. Ultra filtration gave TSS free wastewater, aerobic treatment showed 58.0 to 97.9% TSS removal whereas anaerobic phase has poor TSS removal capacity. The reverse osmosis gave better removal efficiency of COD (70.0 to 90.1%), TDS (90.5 to 94.2%) and BOD (77.7 to 80.0%). The overall treatment showed good performance. Every treatment phase of this effluent treatment process (ETP) has its unique removal capacity, and the treated water of ETP met the effluent discharged standards of world health organization and also fulfills the 4Rconcept called Reduce, Reuse, Recycle and Replenish. Hence this study Strongly recommends combined treatment technologies for all the brewery plants.

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