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# Brewery Waste Water Treatment Using Sequential Batch Reaction: India

Environmental Science

KEYWORDS : Up Flow Anaerobic Sludge Blanket Reactor; Sequential Batch Reactor (SBR); Brewery; Effluent Treatment Plant (ETP); Sludge dry bed.

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## ABSTRACT

*Present research study was conducted for a period of six months to evaluate each and every phase of industry's waste water treatment processes as a cumulative research. The quantity and quality of brewery waste water fluctuates significantly, depending upon operations like raw material handling, wort preparation, fermentation, filtration, controls in process (CIP) and packaging. The water discharged is found to be highly organic in nature with high COD consisting of easily biodegradable sugars, soluble starch, ethanol and volatile fatty acids. This article aims to study the performance evaluation of ETP of a brewing industry located nearby Hyderabad, India.*

*By feeding influent with controlled input parameters like pH, TSS and COD in UASB reactor, considerable reductions in the pollution loads were achieved. It was also found that improved removal efficiency is achieved by maintaining Mixed Liquor Suspended Solids (MLSS), Dissolved Oxygen (DO) and controlled oxygenation in the aerobic treatment. The performance evaluation was indicated that 97- 98% COD removal, 97%99% TSS removal and 98% BOD removal efficiencies were achieved.*

## 1. Introduction

Breweries are the traditional industries in agro and food sector using cost effective techniques to manufacture the best quality product. During the process, beer alternatively passes through three chemical and bio - chemical reactions (Mashing, Boiling, Fermentation and Maturation) and three solid–liquid separations (wort separation, wort clarification and rough beer clarification). Consequently, the water consumption, wastewater generation and solid - liquid separation offer real economic opportunities for the overall improvements in the processes of brewing industries. Wastes generated include glass, paper, card board, plastics, oils, wood, biological sludge, green residues and other industrial solid wastes, while the surplus yeast and spent grains are generated as by products. Brewer's spent grains are used for production of low grade compost, livestock feed or disposed off in landfill as waste (Jay et al., 2004).

Alternatively, the spent grains can be hydrolyzed to produce xylo - oligosaccharides (probiotic effect), xylitol (sweetener) or pentose - rich culture media

(Carvalheiro., 2004 and Duarte., 2004). The mass and water balance is very important for optimization of water consumption, minimizing waste water and conservation of energy. In terms of water management, strict legislations are enforced to reduce water consumption and waste water generation using water management practices. For example, waste water to beer ratio is around 2.0 m3/m3 (based on mass balance) which is difficult to achieve, because part of water is disposed off as by-products and lost by evaporation (Drissen., 2003 and Vereijken., 2003). The effluents discharged are found to have high organic and acidic content, which increases the BOD, COD and high organic load in the waste water contributive to dissolved carbohydrates, alcohols, suspended solids, yeast etc, which pollutes the water bodies considerably (Chaitanya kumar et al., 2011). This particular Brewery industry was had activated sludge process initially in 1997, this is suffering from high energy requirements for the aeration and inconsistency in achieving the effluent standards. Accordingly, the pre aerobic treatment has been replaced with the Up flow Anaerobic Sludge Blanket Reactor (UASB) in the year 2010 with the advantage of not only achieving effluent quality as per Central Pollution Control Board (CPCB) norms but 50% reduction in energy demands. In order to meet demanding requirement of surface water quality, an aerobic polishing after anaerobic pre treatment is suggested. The present research article aims to evaluate performance of brewery industry waste water based on field data and to explore the possibilities of resource recovery from the effluent treatment plant of 400 m3/ day capacity in industry. The overall BOD, COD and TSS removal efficiencies in the effluent treatment plant depends on satisfactory performance of UASB. Combination of anaerobic pretreatment with aerobic post treatment integrates the advantages of reduced energy consumption and limited space requirement.

## 2. Materials and Methods

### 2.1 Brewery Industry

This industry is manufacturing beer using rice, malt and yeast as raw material. The effluent treatment plant ETP selected for the present study (400 $m^3$/day capacity) consists of buffer tank, UASB, Primary plate separator, Aeration tanks, SAFF reactor, parallel plate separator, Sand filter, activated carbon filter and sludge drying beds as shown in Figure 1

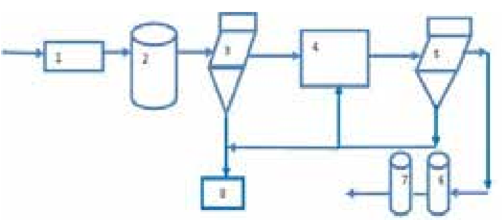

**Figure 1 Flow chart of ETP**

1. Collection Tank; 2. UASB Reactor; 3. Primary Plate Settler; 4. Aerobic Treatment Tanks; 5. Secondary Parallel Plate Settler; 6. Sand Filter; 7. Activated Carbon Filter; 8. Sludge Drying Beds.

### 2.2 Method
From April 2013to Sep 2013 (six months), the waste water samples were collected by grab sampling using sterilized one liter plastic bottles. The sampling was done from UASB reactor, aeration tank, parallel plate separator (secondary) and at the outlet of activated carbon filter for physicochemical analysis for pH, Total suspended solids (TSS), Total dissolved solids (TDS), Volatile fatty acids (VFA), COD, BOD, alkalinity and dissolved oxygen (DO). All samples were transported and analyzed as per standard methods (American Public Health Association, 2005). Table-1 gives the capacities of different units of ETP.

Table- 1 Capacity of different units of ETP

| S. No | Treatment unit | Capacity in $m^3$ | Retention time (hrs) |
|---|---|---|---|
| 1 | Equalization Tank( Buffer Tank) | 450 | 23 |
| 2 | UASB reactor | 290 | 17 |
| 3 | Primary plate separator | 30 | 1.6 |
| 4 | Aeration tank | 400 | 25 |
| 5 | Secondary plate settler | 30 | 2 |
| 6 | Tertiary Treatment Pressure Sand Filter(PSF) and Activated Carbon Filter (ACF) | 20 | 2 |
| 7 | Final outlet | 15 | 2 |
| 8 | Sludge drying bed | - | 15 days |

The treatment units i.e. buffer and aeration tanks have much higher capacities and the treatment process is combination of anaerobic pre treatment with aerobic post treatment. The effluent is fed for anaerobic treatment after being collected in buffering tank which is used to balance the variations in organic loads, pH and flow resulting from batch operation of brewing process as well as the dilution of toxic and inhibiting compounds from the processing plants.

## 3. Results and discussion:
### 3.1 Data Collection and Processing
For statistical analysis, the COD and BOD on monthly basis at inlet and outlet of ETP have been taken into consideration. As the mean of COD and BOD at influent varies in the range of 9600 - 9900 mg/l and 1800 - 2200 mg/l, while after treatment it varies in the range of 97 - 123 mg/l and 17 - 34 mg/l, respectively, the standard deviation (SD) and coefficient of variation (CV) are calculated and presented in the Table-3 and the fluctuations in pollution load are assessed at inlet and outlet of ETP.

The results of table reveal that at the inlet of ETP the COD has the highest mean in the month of May and the lowest in the July. BOD at the inlet of ETP has the highest mean value in the month of April and the lowest in the July. At the final outlet of ETP, the COD has highest mean in the month of August and lowest in May.

The BOD is the highest in the month of April and the lowest in the August. Further, the BOD and COD values at final discharge are within permissible limit of standard prescribed under EPA rules as detailed in Table-2. The performance of anaerobic, aerobic and tertiary treatment was monitored by analyzing the samples collected from inlet and outlet of anaerobic digester, inlet and outlet of aerobic treatment and final outlet after tertiary treatment (Carpenter et al. 2000, Alvarej et al., 2010).

### 3.2 Performance of UASB
The UASB is the main treatment unit for overall COD and BOD removal with formation of granular sludge bed due to higher VSS loadings. The UASB loading was evaluated by measuring its feed rate and discharge of waste water and comparing it with optimum reactor loadings. The variations of volumetric loadings with % age reductions of COD in

UASB is given in Table-4 which shows that COD of influent varies between 9458.00 to 9991.43 mg/l and inflow to the reactor is almost uniform. The volumetric loadings to the reactor are in range from 400 - 800 COD/m3 day against recommended volumetric loadings between 200 - 600 COD/m3 day in the UASB for high TSS and COD removal efficiencies between 96 - 98% and 79 - 88% respectively.

The high BOD and COD removal efficiencies in the UASB are 96 - 99 and 94 - 95% respectively, which may be due to proper functioning of the reactor. The BOD/COD ratio ranges from 0.3 - 0.6 due to the fluctuations in inflows, quantity and quality of the effluent and is a function of various processes like brewing, fermentation and clarification etc. The unit also satisfies the waste management requirements by implementing cleaner technologies. The spent grains are sold as livestock feed (Muroyama et al., 2004, Luc Fillaudeau et al., 2006).

### 3.3 Overall Performance of ETP
The overall percentage reduction of COD, TSS and BOD in the Effluent Treatment Plant has been shown in the Table-5. The results in the table indicate that COD, BOD and TSS meet the discharge standards. During the study of brewery's waste water treatment plant, it has been observed that overall removal efficiencies of COD, TSS and BOD are found as 96 - 98%, 88 - 98% and 99% respectively which is mainly due to considerable reduction of pollution load in the UASB reactor operated under controlled parameters using buffering tank to balance the variations in organic loads and pH.

The value of pH at final outlet has been observed in the range of (7.09 - 7.28) which is within the limit prescribed (5.5 - 9.0) under rules. The remaining treatment units i.e. aeration tank, pressure sand filter and activated carbon filter also work properly giving consistent results at the final outlet of ETP (Chaitanyakumar et al., 2011, Driessen et al., 2003).

| Industry | Parameter | Concentrations in the effluents not to exceed milligrams per litre(Except for pH, colour & odour |
|---|---|---|
| Fermentation Industry (Distilleries, Malteries and Breweries) | pH | 5.5-9.0 |
| | Colour & Odour | All efforts should be made to remove colour and unpleasant odour as for as practicable |
| | Suspended Solids | 100 |
| | BOD(3days at 27o C) disposal into inland surface waters or river streams | 30 |
| | Disposal On land or for irrigation | 100 |

**Table-3 Statistical analysis of COD and BOD data**

| Period | COD mg/L | | | | | | BOD mg/L | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inlet of ETP | | | Outlet of ETP | | | Inlet of ETP | | | Outlet of ETP | | |
| | Mean | SD± Mean | CV (%) | Mean | SD± Mean | CV (%) | Mean | SD± Mean | CV (%) | Mean | SD ± Mean | CV (%) |
| April | 9976.55 | 857.61 | 8.60 | 123.93 | 15.88 | 12.81 | 2267.24 | 795.78 | 35.10 | 34.14 | 12.96 | 37.97 |
| May | 9991.43 | 943.33 | 9.44 | 123.93 | 15.88 | 12.81 | 2208.62 | 781.72 | 35.39 | 34.14 | 12.96 | 37.97 |
| June | 9774.67 | 711.02 | 7.27 | 101.97 | 30.34 | 29.75 | 1816.67 | 1027.58 | 56.56 | 21.17 | 14.30 | 67.58 |
| July | 9458.00 | 2057.25 | 21.75 | 108.63 | 30.31 | 27.90 | 721.00 | 1128.31 | 156.49 | 26.17 | 14.54 | 55.58 |
| August | 9639.33 | 1042.47 | 10.81 | 97.60 | 21.42 | 21.94 | 1540.00 | 1112.50 | 72.24 | 17.67 | 14.96 | 84.66 |
| September | 9847.00 | 1666.22 | 16.92 | 103.70 | 19.14 | 18.46 | 1861.67 | 1669.85 | 89.70 | 24.33 | 11.58 | 47.58 |

**Talbe-4 Volumetric loadings with COD, BOD and TSS removal in USAB**

| Period | Flow M3/Day | COD Mg/L | | COD Removal Efficiency | Volumetric Loading Rates (Kg COD/M3.D) | BOD | | BOD Removal Efficiency | TSS Mg/L | | TSS Removal Efficiency |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inlet | Outlet | | | Inlet | Outlet | | Inlet | Outlet | |
| April | 806.1 | 9976.6 | 123.9 | 98.8 | 551.0 | 2267.2 | 34.1 | 98.5 | 3258.6 | 65.9 | 98.0 |
| May | 806.1 | 9991.4 | 123.9 | 98.8 | 551.0 | 2208.6 | 34.1 | 98.5 | 3258.6 | 65.9 | 98.0 |
| June | 679.2 | 9774.7 | 102.0 | 99.0 | 699.3 | 1816.7 | 21.2 | 98.8 | 3262.0 | 36.3 | 98.9 |
| July | 778.7 | 9458.0 | 108.6 | 98.9 | 800.3 | 721.0 | 26.2 | 96.4 | 1859.3 | 31.3 | 98.3 |
| August | 1041.3 | 9639.3 | 97.6 | 99.0 | 521.2 | 1540.0 | 17.7 | 98.9 | 2965.2 | 29.0 | 99.0 |
| September | 1046.9 | 9847.0 | 103.7 | 99.0 | 400.4 | 1861.7 | 24.3 | 98.7 | 3093.3 | 36.3 | 98.8 |

The removal efficiencies shown in summarized table indicate that ETP works properly and can be role model for other breweries.

## 4. Conclusions

The performance of ETP installed in this industry has been found to give high COD, BOD and TSS removal efficiencies. The treated effluent water is found to meet the effluent discharge standards. In order to further improve the performance of the ETP, the following action plans are recommended. The above study recommended to following action plan for the resource recovery to make ETP sustainable for conservation of energy and water.

- The secondary settling rates may be enhanced with provision of regular sludge recirculation in aeration tanks and to maintain optimum level of MLSS.
- Existing conventional activated sludge process may be modified to SBR for saving power and making the treatment sustainable.
- The methane from UASB should be used as fuel in the boiler to reduce pet coke consumption used presently as fuel.
- The treated effluent from the ETP should be recycled for non potable use and in order to reduce the dependency on the fresh water supply.

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