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Performance evaluation of brewery biological wastewater treatment plant - a case study

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Abstract

This study was conducted to evaluate the performance of biological treatment plant of a brewery located at Rajasthan, India. The biological treatment consists of anaerobic treatment through anaerobic hybrid reactor (AHR) and conventional aerobic treatment (Activated Sludge Process (ASP)). The results showed that the COD removal efficiencies ranged between 46.96 % - 89.71% for anaerobic treatment at an Organic Loading Rate of 0.9 – 3.6 kg COD/ m^3/day. The COD removal efficiency after aeration was in range of 12% to 74%, making overall removal efficiencies of COD after Anaerobic (AHR) and Aerobic system to be between 75% to 97%. This paper includes effluent characterization, treatment scheme and performance of a brewery ETP under study. In addition to it, the problems associated with the operation and maintenance of brewery Effluent Treatment Plant was discussed and suitable recommendations were made based on its performance.

Keywords: Brewery, Effluent Treatment Plant, BOD, COD, TDS, Anaerobic Hybrid Reactor (AHR), Activated Sludge Process (ASP).

1. Introduction

Brewing is the process is for production of beer (Chaitanyakumar et al. 2011, Beyene and Rao 2013). It is said that for every 1 liter of beer production approximate 10 liters of water is used (Al-Rajhia et al. 2012). The water in any brewery is typically used for brewing, rising and cooling process (Al-Rajhia et al. 2012). The various steps that are involved in brewing process are malt production and handling, wort preparation, fermentation, filtration, CIP and finally packaging (Chaitanyakumar et al. 2011, World Bank 1997, Klijnhout and Van Eerde 1986, Akula et al. 2014). The quality and quantity of effluent generated through various processes depend upon the water consumed in each process (World Bank 1997). Brewery effluent is characterized by high organic load and high acidic content (Beyene and Rao 2013, BAWW, Inyang et al. 2012, Simate 2011). It consists of soluble sugar, soluble starch, carbohydrates, ethanol, volatile fatty acid, suspended solids and yeast etc (World Bank 1997, Al-Rajhia et al. 2012, Akula et al. 2014). Most of the organic present in brewery wastewater is biodegradable. COD to BOD ratios ranges from 1.5 – 2.0 (World Bank 1997, Enitan et al. 2015). Several methods were used to treat the effluent generated from the brewery. Physical method is used to remove the coarse matter present in effluent. Chemical method can be employed to remove the suspended impurities. Biological treatment method like anaerobic and aerobic treatment results in removal of high COD and BOD present in wastewater (World Bank 1997, Al-Rajhia et al. 2012). Wastewater from brewery doesn't contain adequate quantity of nitrogen required for biological oxidation due to which external nitrogen nutrients are required to be added into the aeration basins (Bodike and Thatikonda 2014). Anaerobic, aerobic and reverse osmosis treatment provides better removal efficiency for brewery effluent (Chaitanyakumar et al. 2011, Beyene and Rao 2013).

Bio-remediation methodology with anaerobic treatment can remove 90-98% of high COD present in brewery wastewater. Pseudomonas, gram negative bacteria has been found to act actively at a very high pH, bringing pH down from 10.2 to 8.67 (Klijnhout and Van Eerde 1986). It has tested to reduce concentration of carbohydrates by 54% and proteins by 25% in brewery effluent. The study of microbial consortia (Cronobacter sp. strain NGS4, Pseudomonas fluorescent NGS5, and Aeromonas sp. strain NGS7) with optimal oxygen flow (aeration), retention time and temperature showed reduction of COD by 67%, BOD by 79% and TSS by 50% (Anggraeni et al. 2014). The factors that affect the microbial ecology and characteristics of anaerobic reactors include Organic Loading Rate (OLR), Hydraulic Retention Time (HRT) and uplow velocity (Jafarzadeh et al. 2013). Anaerobic Hybrid Reactor (AHR) under thermophilic condition (55°C) with an 5.5g COD/ day OLR and 10 days HRT offered 90% COD removal with high methane yield i.e.0.32 g CH_4/g COD removal was established through experimentation (Wanitanukul et al. 2013). Under mesophilic conditions (35°C) high TCOD removals ranging between 42- 86% at a OLRs of 0.5-24.0 Kg COD $m^{-3}d^{-1}$ and HRT 4-6 hours were achieved through studies (Jafarzadeh et al. 2013). Operational study for 2 years in Expanded Granular Sludge Bed reactor depicted 95% of COD conversion into gas and solid digestion with proper COD solubility and efficient EGSB mixing (Radu et al. 2014).

98% COD, 99% TSS and 98% BOD removal rate were observed in brewery effluent treatment plant having UASB reactor followed by Sequential Batch Reactor (SBR) (Sharda et al. 2013). The advanced treatment technologies like SBR and membrane technologies provide an effective method of treating effluent. Additional advantage of latest technology is less power usage and reduction in plant footprint area (Sharda et al. 2013). The comparative performance evaluation of aerobic treatment technologies on food industry effluent depicted highest BOD and COD reductions in case of fluidized aerobic biological reactor (FABR) than activated sludge process (ASP), stabilization pond and rotating biological contactors. The COD, BOD removal efficiencies through FABR was 85% and 91% respectively. ASP process showed 84% reduction in BOD and 90% reduction in COD. The reduction in case of Stabilization Pond and RBC was less than 79% (Banwade et al. 2015). Energy saving analysis at sewage treatment plant demonstrated that power consumption can be reduced by 7 to 17% by controlling settings for MLSS, Return Sludge Ratio and Rector Dissolved Oxygen (Fukushima et al. 2013).

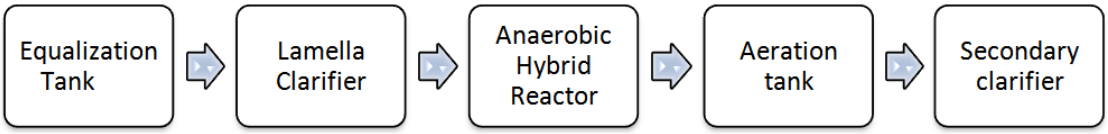
Reducing the water use and recycling the effluent are the two main factors that focus on the conservation of water. It will result in reduction of water and wastewater positively in brewery (BAWW). Stringent pollution control regulations, scarcity of fresh water and high cost of wastewater disposal has result in installation of Zero Liquid Discharge (ZLD) plants in past few decades (Tong and Elimelech 2016, ZLD 2013). ZLD system treats and recycles wastewater leaving no liquid discharge at the end. Reverse Osmosis, Ultra filtration, Evaporators etc form the part of zero discharge mechanism process. ZLD system reduces water pollution and increases water sustainability (Tong and Elimelech 2016). Many ZLD systems have been installed in various breweries across globe to control the water pollution loads and recycle reuse the wastewater generated through the process.

2. Materials and method

Effluent Treatment Plant of a Brewery selected for study was located at Rajasthan, India. The data for the month of October was taken for the study starting from 1 Oct 2016 to 31 Oct 2016. The inlet and outlet characteristics were measured at particular point before and after each process unit. The sample for measuring the effluent characteristics was taken using sterilized plastic bottle of capacity one liter.

Effective effluent management is the most important aspect in any industries. It improves the cost effectiveness of their production process also evade heavy discharge penalties. With growing crisis of ground and surface water in India, it has become imperative for major water intensive industries like brewery to introduce reuse/ recycling of treated effluent back into the process. The brewery effluent treatment plant under study has primary and secondary treatment facility.

Process flow diagram of Brewery ETP understudy were as below



All parameters were analyzed in accordance with standard methods American Public Health Association.

3. Results and discussion

Equalization tank pH under study for a month ranges from 6.4 to 7.75. The quantity and quality of effluent is fluctuating.

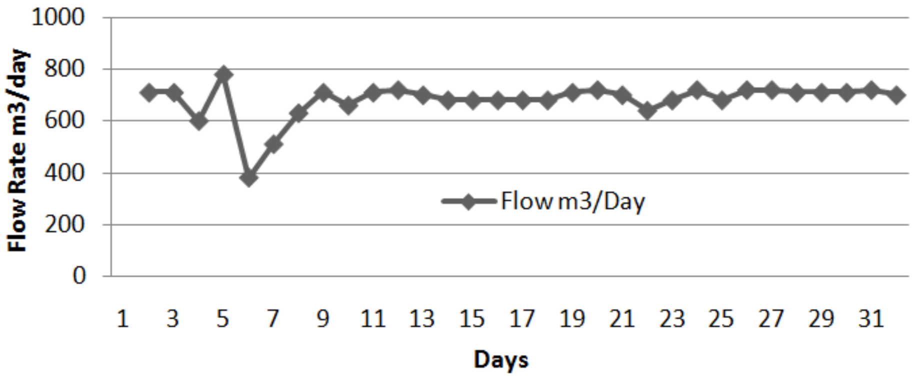


Fig. 1. Graph of effluent flow rate (m^3/day).

Performance of Anaerobic Hybrid Reactor (AHR)

The performance of anaerobic digestion is dependent on Organic loading, C/N ratio, and the strength and amount of inoculums. Methanogenesis process is inhibited by an imbalanced Anaerobic Digestion caused by high organic loading and C/N ratio, accumulation of VFA and low pH (Frigon and Guiot 2010). Anaerobic treatment method through AHR is used to remove overall COD and BOD. AHR or Anaerobic Hybrid Reactor is generally combination of suspended and attached growth process. It is very prevalent in high strength wastewater.

COD of influent varies from 1241 mg/l – 4460 mg/l in the month of October understudy. The Organic loading rate varies between 0.9 – 3.6 kg COD/ m^3/day. pH of the effluent also act as an important parameter in determining the functioning of digester. pH range between 6.4 – 7.6 ensures normal functioning of digester. It is said that the methane forming bacteria are more sensitive to a slight changes in OLR, pH and Temperature as compared to the acid forming bacteria. More acid forming bacteria will result in excess volatile acids and thus upsets the digester. OLR ranging from 3.5 – 4.5 kg COD/ m^3/ day and HRT = 2 days, AHR has achieved the soluble COD removal efficiencies of 97-99% (Wang et al. 2004).

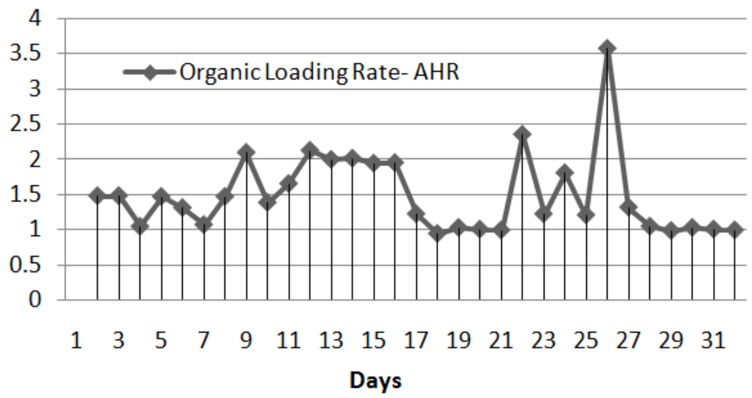


Fig. 2. Organic Loading Rate (AHR) Kg.

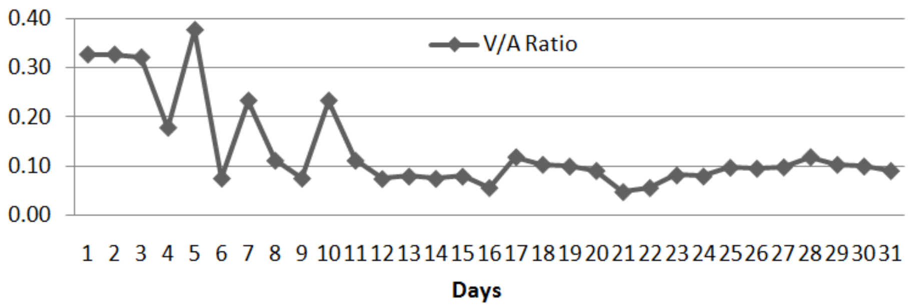


Fig. 3. VFA/ Alkalinity Ratio.

A complex multi-biomass and multi- substrate process in which COD is decomposed firstly into volatile fatty acids (VFA) and after that into biogas, microbial biomass and residual matter is Anaerobic Digestion. (Alcazar-Gonzalez et al. 2015). VFA to total alkalinity ratio and bicarbonate alkalinity to total alkalinity ratio can predict the health of digesting system. It can provide early warning of process failure due to acidification of anaerobic digestion (Li et al. 2014). The methane yield can be improved by reducing the particle size but excessive reduction may cause VFA accumulation. According to the studies conducted on food waste the optimum particle size for effective methane yield is 0.6 mm. The VFA/ alkalinity ratio was determined using empirical formula to determine the risk of acidification (Anderson and Yang 1992).

The VFA to Total Alkalinity varies from 0.05 – 0.38 during the one month duration of studies. Since, the VFA to alkalinity ratio is less than 4, it indicates that the digester is stable (Pandey et al. 2009).

In other research studies conducted have shown that maximum concentration of biogas produced is at 8 h HRT, it corresponds to the favorable operating environment and good system stability ratio (VFA/Alkalinity) < 0.5 achieved (Okonkwo et al. 2013).

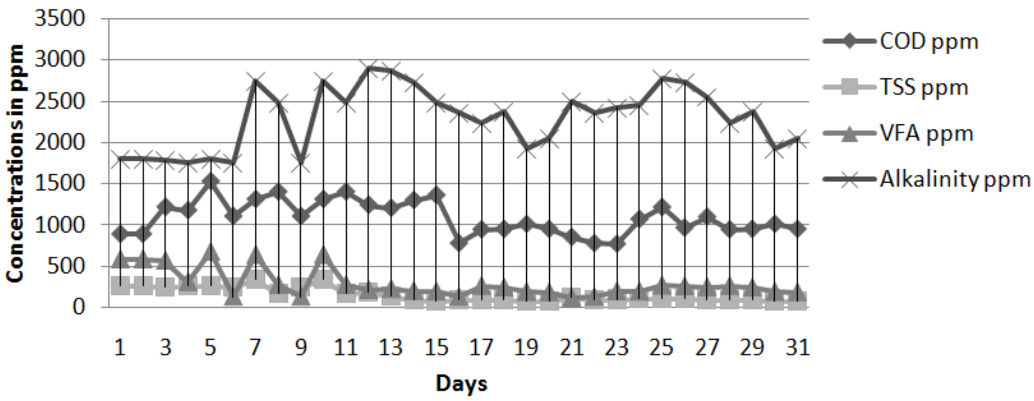


Fig. 4. AHR outlet data.

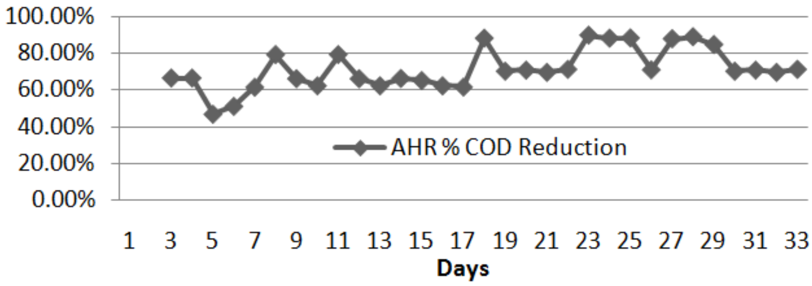


Fig. 5. % COD reduction in AHR.

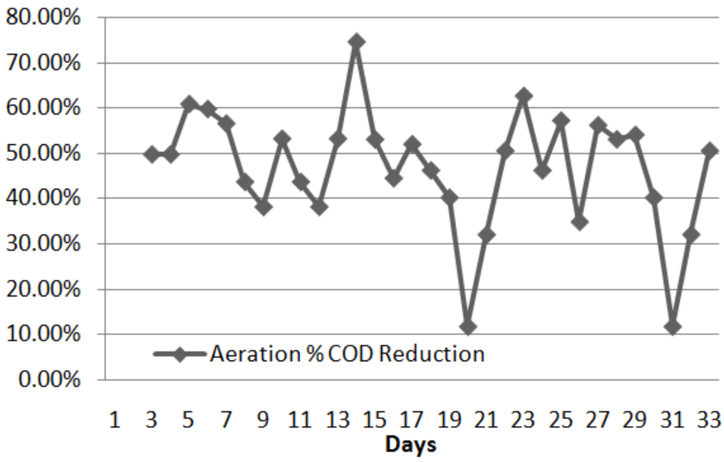


Fig. 6. % COD reduction after Aeration.

The COD removal efficiency was ranging from 46.96 % - 89.71%. On a whole, we observed that the performance of the Anaerobic Hybrid Digester is satisfactory and the digester is stable.

Performance of aeration process

The pH ranged from 7.6 to 8.4. COD values gradually decreased from Aeration tank to Secondary Clarifier. The MLSS ranged from 3500 to 5700 mg/L in Aeration Tank-1 and 3200 to 5100 mg/L in Aeration Tank-2. COD removal was from 12% to 74% whereas it has less effect on TDS. Poor settling was observed at secondary clarifier. There are the fluctuations observed in the effluent load entering into the aeration basin due to which the treated outlet parameters are also fluctuating. The COD range at the outlet of secondary clarifier is from 67 mg/L – 435 mg/L which is much more than that specified by pollution control board. COD removal efficiency is lowered with an increase in organic loading rate. Variation in the results can be controlled by maintaining the proper dissolved oxygen level in aeration basin. An ETP operator ensures enough oxygen in aeration tanks for microorganisms (typically 1.0-3.0 mg/L) for optimal performance (WDNR 2010). It has been inferred from the research that for a higher strength wastewater attached growth process offers better performance. High specific surface area and low sludge production are the advantage of attached growth process (Abdulgader 2007).

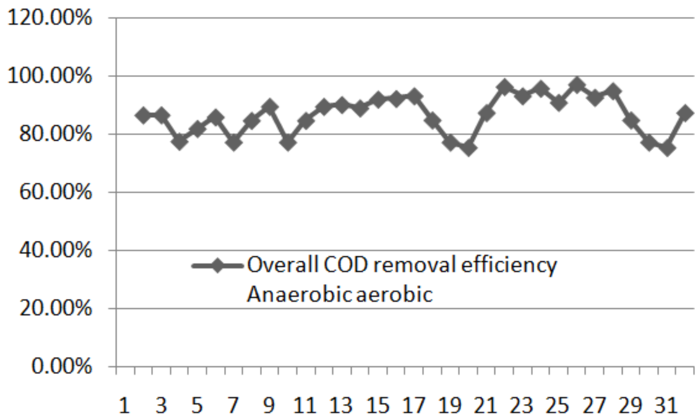


Fig. 7. COD reduction after Anaerobic and Aeration Treatment.

4. Conclusion

Brewery uses large volumes of water. The effluent generated in brewery is organic in nature and is easily biodegradable. Anaerobic system followed by aerobic proposes to be the most cost effective and efficient method of treatment. COD removal efficiency after Anaerobic (AHR) and Aerobic system was found to vary between 75% - 97% during the duration of study. To check stability of Anaerobic Hybrid Reactor close monitoring of VFA to total alkalinity should be done. VFA to Total Alkalinity should be less than 4 for a stable anaerobic system. Outlet parameters observed after treatment are not in line with the norms specified by Pollution control board in India. This is due to less effective aeration system. Aeration tanks should be sufficiently aerated so as to keep the biological content in suspended form. The dissolved oxygen level should be maintained > 1ppm at all levels. An attached growth process can also be adopted to improve aeration process efficiency. MLSS content should be in range of 3500-4500 mg/L, as excessive MLSS results in to drop of dissolved oxygen level and process is prone to bulking whereas less MLSS results in to loss of energy.

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