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Impact of varying hydraulic retention time for treating distillery effluent in activated sludge system to combat the environmental and health hazards

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***Abstract*---**Ethanol-distilleries are the key supporter to the world's economy, but these are moreover one of the major sources of environmental pollution that can impact the human heath if the effluents are not treated in proper manners. Distillery effluents with high biological oxygen demand (BOD) and chemical oxygen demand (COD) contains toxic chemicals which are reported to be of carcinogenic and mutagenic in nature. One of the widely used technology for the distillery wastewater treatment is based on up-flow anaerobic sludge blanket (UASB) technology along with activated sludge process. This technology has fulfilled a need for high efficiency treatment of wastes from various distilleries. With the increasing demands of distillery units and strict guidelines by government agencies for the environment protection, more efforts are required to achieve the zero liquid discharge (ZLD). The research reported in this paper is an effort to perform the *in-situ* study for evaluating the impact of varying retention times on the efficiency of the condensate Polishing Unit (CPU) based on UASB technology along with activated sludge process for ZLD. The primary objective was to determine pH, BOD and COD after increasing the HRTs in the aeration tank. Results revealed the positive effect of prolonged HRTs on reduction of BOD and COD loads from the samples collected from the CPU outlet. Our study clearly indicated that the increase in the hydraulic retention time enhances the efficiency of the CPU based on Activated sludge process

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of distillery units. This technological advancement could serve as emerging waste water treatment methods for the environment and human health protection.

***Keywords*---**activated sludge process, BOD, COD, condensate polishing unit, hydraulic retention time (HRTs), zero liquid discharge (ZLD).

Introduction

A serious challenge for the future is to provide the entire world with clean and toxin-free water that would otherwise have serious impacts on human health. However, there is an increase in the consumption of fresh water in various industries including distilleries. The ethanol-manufacturing in distilleries is a water-intensive process because it consumes heavy volumes of fresh water and generates a huge amount of effluent discharge (Nandy et al., 2002; Liu et al., 2019). Various studies have shown that the distillery effluents contain the presence of various types of organic and inorganic pollutants that could severely impact the endocrine system, causes the hormonal imbalance, and effect the reproductive system of human and animals that eventually lead to the cancer (Ghosh et al., 2003; Pandey et al., 2003; Sharma et al., 2007; Ayub et al., 2012; Chowdhary et al., 2018).

Due to these environmental and health hazards, distillery effluents must be treated properly so that organic and inorganic pollutants are completely degraded and detoxified before discharging them in the environment. Strenuous efforts have been made to implement the economically feasible methods for distillery waste treatment both in India and across the world. The wastewater from the distilleries is treated on a massive scale using various physical, chemical, and biological methods (Mohana et al., 2007; 2009). The COD/BOD ratio determines whether biological treatment is required or not. When the COD/BOD ratio is larger than 1.5, then the biological treatment is the best option for handling distillery wastewater (Metcalf & Eddy 2003).

Tropical and subtropical countries like India utilises the bacteria for decomposing the different types of waste. Currently in India, high proportion of distilleries has adopted activated sludge process in condensate polishing unit to treat the highly polluted condensates from the distillery units (Pandey et al., 2003; Sharma et al., 2007; Ayub et al., 2012; Patyal, 2015; Ruhela et al., 2020). Distilleries have installed condensate polishing units based on up-flow anaerobic sludge blanket (UASB) technology along with activated sludge process (Patyal, 2015; Ruhela et al., 2020). These technologies are necessary for sustainable development and requires valorisation strategies to achieve zero liquid discharge (Mikucka and Zielińska, 2003). However, the available technologies of wastewater treatment are techno-economically limited. Under current scenario, an efficient and practically feasible strategy is deemed to accomplish the Zero liquid discharge. It is plausible that activated sludge process with certain modifications is a suitable and practical mode to achieve the desired standards and reduce water footprint by distillery units (Tiwari et al., 2021).

This paper presents a case study based on an industrial process of ethanol distillation and the effluent treatment in CPU based on UASB technology along with activated sludge process, where the minimization of wastewater is achieved by increasing the hydraulic retention time in the aeration tank. In aeration tank of CPU based on the activated sludge process, there are various components that influence its efficiency, namely hydraulic retention time (HRT), and density of micro-organism i.e., bacteria or food/mass ratio (Almasi et al., 2016; ElNaker et al., 2018). The HRT is the average time holding the wastewater in the tank. The reduction in the HRT decreases the multiplication of aerobic microbes which results in reduced concentration of microbes in aeration tank (Pan et al., 2004; ElNaker et al., 2018). Therefore, the HRT is very crucial component of CPU to regulate the microbial cell densities in the tanks. In this paper, we have studied the impact of increasing the HRT on the pH, BOD and COD levels of aeration tank of CPU based on UASB technology along with activated sludge process. This could be very promising technological advancement that can improve the status of waste water and reduce the toxic nature of the effluents and thereby protecting the environment and human health.

Materials and Methods

Sampling

The effluent samples were collected from the distillery unit with waste-water treatment technology based on UASB technology along-with activated sludge process. The samples were collected from the aeration tank and CPU outlet. The CPU flow diagram is shown in Figure 1.

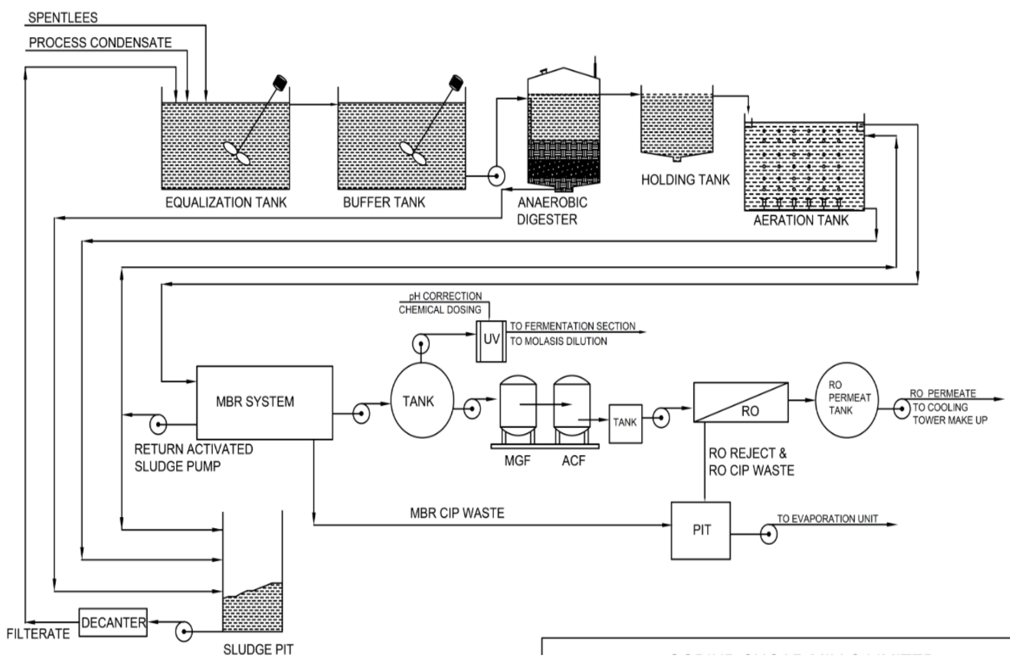

Figure 1 The process flow diagram of existing Condensate Polishing Unit (CPU) at the study site

Experimental design

Tank type for sampling	1. Aeration Tank	2. CPU Outlet
Hydraulic retention time (HRTs)	At three time-points i.e., 20 hrs, 24 hrs and 28 hrs	
Replicates	Total 3 biological replicates and 2 technical replicates were taken for each time-point	
Parameters	1. pH 2. BOD 3. COD	
Independent repeats	Experiment was conducted twice for 2 consecutive months	
Statistics	Standard deviation and standard error of mean were calculated, and statistical significance was calculated by applying one-way ANOVA (p value < 0.05)	

The collected samples were labelled properly, stored and then transported to the laboratory where further tests were performed. The parameter of pH was recorded on-site. The American public health association (APHA, 23rd ED. 2017) guidelines were followed during all the procedures of sample collection, handling and testing.

Methodology as per APHA Protocol

Sr.No.	Parameter	Container	Sample Size	Preservation	Reference
1	pH	Plastic, Glass	1000 ml	-	APHA 23rd Ed. 2017 Page 1-44 to 1-45
2	BOD (Indicator of water pollution)	Plastic, Glass	1000 ml	Cool, <6˚C	IS 3025 (Part-44) 1993 Reaffirmed 2019 (3 Days, 27°C method).
3	COD (Indicator of water pollution)	Plastic, Glass	1000 ml	H_2SO_4 to pH<2, Cool <6˚C	APHA 23rd ED 2017 – 5220 B (PP 5-18 to PP 5-19)

The physicochemical parameters such as pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), were analysed as per standard method APHA, 23rd ED 2017. The results obtained were compared at different hydraulic retention times.

Results and Discussion

The pH, BOD and COD data were obtained for the effluent samples collected from the aeration tank and CPU outlet after increasing the hydraulic retention time (HRTs) and the results are presented in Table -1 and Figure. -2. The average pH was determined for the effluent samples collected from the aeration tank and CPU outlet at different HRTs i.e., 20 hrs, 24 hrs and 28 hrs. The pH values of samples collected from the aeration tank at 20 hrs, 24 hrs and 28 hrs are 6.6, 6.5 and 6.8 respectively. The pH values for the samples collected from the CPU outlet at 20 hrs, 24 hrs and 28 hrs are 6.8, 7 and 7.2 respectively (Table 1). These data indicates that there was no significant difference in the pH values across all the time-points used in this study. Therefore, the parameter of pH is almost consistent for the aeration tank and CPU outlet even after increasing the hydraulic retention time (HRTs) of the aeration tank.

Table 1. Determination of pH values of the effluent samples after increasing the hydraulic retention time (HRTs).

Name of tank	Time-point	Month 1	Month 2
Aeration tank	20 hrs	6.6	6.4
	24hrs	6.5	6.6
	28 hrs	6.8	6.8
CPU outlet	20 hrs	6.8	6.5
	24hrs	7	6.6
	28 hrs	7.2	7

The BOD values were estimated at the three different HRTs time-points for the samples obtained from aeration tank and CPU outlet. The approximate BOD values of the samples collected from the aeration tank at 20 hrs, 24 hrs and 28 hrs are 225 mg/L, 220 mg/L and 155 mg/L respectively (Figure 2A). This indicates that the BOD values of the samples from the aeration tank were significantly reduced (at p-value<0.05) at retention time of 28 hrs compared to 24 and 20 hrs (Figure. 2A). Further, the approximate BOD values of the samples collected from the CPU outlet at 20 hrs, 24 hrs and 28 hrs are 10 mg/L, 8 mg/L and 4 mg/L respectively. The BOD values of CPU outlet were significantly reduced (at p-value<0.05) in samples collected at retention time 28 hrs, then in 24 hrs and followed by 20 hrs (Figure 2A). The experiment was repeated for another consecutive month and the consistent trend was observed in the BOD values of the samples collected from the aeration tank and CPU outlet at three different HRTs. Overall, the data indicates that increase in the HRTs in the aeration tank is effective enough to reduce the BOD loads in the samples.

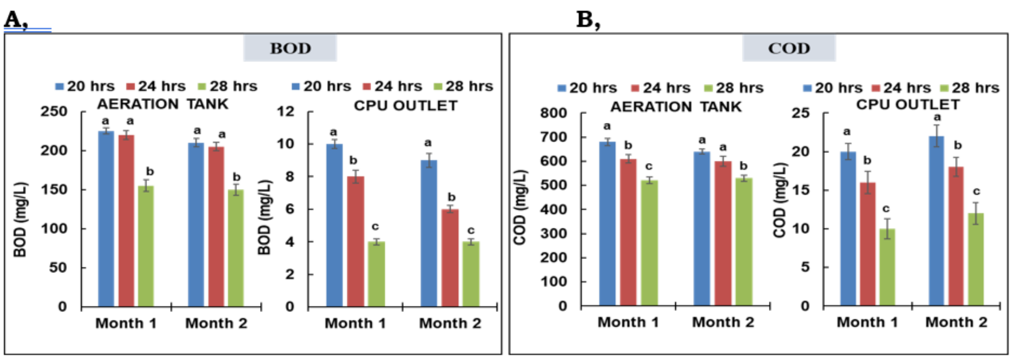

Figure 2 The A, BOD and B, COD analysis from effluent samples from aeration tank and CPU outlet after increasing the hydraulic retention time (HRTs)

Next, the COD values were estimated at the three different HRTs time-points for the samples obtained from aeration tank and CPU outlet. The approximate COD values of the samples collected from the aeration tank at 20 hrs, 24 hrs and 28 hrs are 680 mg/L, 610 mg/L and 520 mg/L respectively (Figure. 2B). The data indicates that the COD values of the samples from the aeration tank were significantly reduced (at p-value<0.05) at retention time of 28 hrs compared to 24 and 20 hrs. Further, the approximate COD values of the samples collected from the CPU outlet at 20 hrs, 24 hrs and 28 hrs are 20 mg/L, 16 mg/L and 10 mg/L respectively (Figure. 2B). The COD values of CPU outlet were significantly reduced (at p-value<0.05) in samples collected at retention time 28 hrs, then in 24 hrs and followed by 20 hrs. The experiment was repeated for another consecutive month and the consistent trend was observed in the COD values of the samples collected from the aeration tank and CPU outlet at three different HRTs. Overall, the COD analysis indicates that increase in the HRTs in the aeration tank is efficient to reduce the COD levels in the effluent samples.

The up-flow anaerobic sludge blanket (UASB) technology along with activated sludge process is the most efficient technology to treat condensates of distilleries (Tiwari et al., 2021). Although, this technology is efficient enough to manage the waste-water effluent from the distilleries to meet out the prescribed guidelines of pollution control board (PCB) (Kumara-Adi and Savitri, 2019). However, with the increase in the ethanol production and the establishment of new distilleries units, there is an immense need to improve the existing waste-water treatment strategies. One of the ways to combat the effluents from the distilleries and to achieve the zero liquid discharge is by increasing the hydraulic retention time (HRTs) in the aeration tank. This study clearly suggests that the increase in the retention time is effective in reducing the BOD and COD levels of the effluents. Moreover, the promising outcomes obtained from this study could be fruitfully utilized to manage the water footprints at industrial level.

Conclusion

Pollution prevention mainly focuses on restricting the waste generation with simultaneous waste minimization by water recycling and reuse, thereby achieving the environment sustainability. Water recycling and reuse could make sense only when the wastewater is treated properly and does not contain harmful pollutants which would otherwise impact the human health. In the present study, it was found that the BOD and COD values of effluents from the aeration tank were reduced after increasing the hydraulic retention time in the aeration tank. The implementation of increased retention time in the CPU based on UASB along with activated sludge process is efficient in reducing the BOD and COD levels and this treated water could be considered as an environmentally fit to re-use in various human and industrial needs. Therefore, the adaptation of this technology allows the recycling of treated wastewater, thereby limiting the water footprint in the distilleries without compromising human and environmental health.

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